NASA Technical Memorandum 100720

MODIS Information, Data, and Control System (MIDACS) Operations Concepts

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D. Han, V. Salomonson and J. Ormsby
Space Data and Computing Division
Goddard Space Flight Center
Greenbelt, Maryland

P. Ardanuy, A. McKay, D. Hoyt, S. Jaffin and B. Vallette
Research and Data Systems
Greenbelt, Maryland

B. Sharts and D. Folta
General Sciences Corporation
Laurel, Maryland

E. Hurley and D. MacMillan
Interferometrics, Inc.
Vienna, Virginia

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National Aeronautics and
Space Administration

Information Management Division

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PREFACE

The purpose of the MODIS Information, Data, and Control System (MIDACS) Operations Concepts Document is to provide a basis for the mutual understanding between the users and the designers of the MIDACS, including the requirements, operating environment, external interfaces, and development plan. In defining the concepts and scope of the system, this document will describe how MIDACS will operate as an element of the Earth Observing System (EOS) within the EosDIS environment. This version of the Operations Concept follows the earlier release of a preliminary version. The individual operations concepts for planning and scheduling, control and monitoring, data acquisition and processing, calibration and validation, data archive and distribution, and user access do not yet fully represent the requirements of the data system needed to achieve the scientific objectives of the MODIS instruments and science team. Indeed, the team members have not yet been selected and the team has not yet been formed. However, it has been possible to develop the operations concepts based on the present concept of EosDIS, the Level-I and Level-II Functional Requirements Documents, and through interviews and meetings with key members of the science community. The operations concepts have been exercised through the application of representative scenarios.

The study team is indebted to: Wayne Esaias, Chris Justice, and Joel Susskind for detailed information regarding the science requirements; Bill Barnes, John Barker, and Bruce Guenther for information regarding MODIS instrument concepts; H. Lee Kyle, and Dick Stonesifer for their insight into aspects of data processing, instrument control, and data storage; and to Al Fleig for his assistance in applying the guidelines being set forth by EosDIS.

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1. INTRODUCTION

The global Earth Observing System (EOS) is made up of the U.S. and its international partners. The data processing, distribution, and management element, the Data and Information System, under the NASA EOS Project, are called the EosDIS. The EosDIS is planned as a remote sensing system providing data acquisition, receipt, processing, management, and distribution support for the Earth observation data acquired by the instruments on board the NASA Polar Orbiting Platform (NPOP). Two of the many instruments scheduled to be on the first NPOP (NPOP-1) are the Moderate Resolution Imaging Spectrometer-N (MODIS-N) and MODIS-T instruments. In order to support the MODIS instrument complement, an EosDIS-unique element is necessary. This unique element is the MODIS Information Data and Control System (MIDACS).

1.1 PURPOSE

The purpose of the MODIS Information, Data, and Control System (MIDACS) Operations Concepts Document is to provide a basis for the mutual understanding between the users and the designers of the MIDACS, including the requirements, operating environment, external interfaces, and development plan. In defining the concepts and scope of the system, this document will describe how MIDACS will operate as an element of the EOS within the EosDIS environment.

1.2 SCOPE

The MIDACS fulfills the responsibilities of instrument monitoring and control, as well as data acquisition, management, production, certification, and distribution. In order to design the MODIS data system to efficiently and reliably fulfill each of these functions, the system's operational concepts must be clearly stated. It is recognized that these concepts will evolve as information is compiled, the science team formed, and the instrument design refined. This document will mature in response to evolutions in the scientific and functional requirements. In this preliminary report all MIDACS concepts are addressed, although some specific facility concepts are not fully identified. These will be completed in a later draft.

1.3 MODIS INSTRUMENT

The MODIS instrument will be composed of two components: the MODIS-T, a "tiltable" cross-track scanner, and the MODIS-N, a nadir-viewing cross-track scanner. As currently envisioned, the instruments will provide multi-year, continuous terrestrial coverage across a nearly 2000-kilometer swath with 104 channels covering the visible, near-infrared, and thermal infrared spectral regions. The channels have been selected to provide terrestrial, oceanographic, and meteorological observations at spatial resolutions ranging from one kilometer to 250 meters at nadir.

As a consequence of the design of MODIS, a high data rate and an extremely large data archive volume are anticipated. Furthermore, specific aspects of the EosDIS combine to shape the processing requirements for the MODIS data system; in particular, the release of certified data products in accessible, long-term archives.

1.4 REFERENCES AND APPLICABLE DOCUMENTS

a. EosDIS Baseline Report, CTA, July 29, 1988.

b. Earth Observing System Data and Information System Report of the EOS Data Panel, Vol. IIa, NASA, 1986.

c. EosDIS Control Center Concepts, Vol. 2.1, February 25, 1988.

d. EosDIS Pre-Phase B System Design Concept Report, CTA, January 1988.

e. EosDIS Control Center Concepts, EosDIS Planning and Scheduling Scenario, October 11, 1988, Code 510.1/Steve Tompkins.

2. MODIS OPERATING ENVIRONMENT

2.1 MIDACS/EosDIS ENVIRONMENT

MODIS has been designated as a GSFC facility instrument on the first NASA polar orbiting platform, NPOP-1, scheduled for launch in 1996. It is the responsibility of NASA to provide a ground system by that time which will control the operation of the MODIS instrument on board the platform and perform the data acquisition, processing, and distribution functions to serve the user community.

NASA's Goddard Space Flight Center (GSFC) is responsible for the design and development of the MODIS ground system, MIDACS. This ground system will be one of the elements operating in the context of the overall EosDIS. The EosDIS will be responsible for the end-to-end data flows involving the Tracking and Data Relay Satellite System (TDRSS) and its ground terminals at White Sands, the various EOS ground systems, and the users. Figure 1 describes the EosDIS environment under which the MIDACS will operate. The following sections provide a brief description for each of the systems in the EosDIS and MIDACS environments.

2.1.1 MODIS Flight Data System

A flight data system will be available for each instrument on the EOS platform. The functions of the flight data system include instrument commanding and collection of observation data. For MODIS, the platform local area network (LAN) will provide support for the transfer of science, engineering, and ancillary data as well as the platform core ancillary data, command loads, and other management functions. Data will be encapsulated by the MODIS instrument in formatted packets based on recommendations of the Consultative Committee for Space Data Systems (CCSDS) for transfer on the LAN.

2.1.2 EOS Platform Flight System

The platform architecture is based on orbit replacement units (ORUs) which contain specific payloads, of which MODIS is one, that are connected to the LAN. The control of MODIS and other instruments are provided by a data management system. This control encompasses allocation of operation resources, timing functions, and common services such as on-board storage. The platform flight system will provide for transmission and reception of all data to and from the ground via the TDRSS.

2.1.3 External Interfaces

Figure 2 provides a context diagram of the MIDACS and shows the external elements it will interface with. The following describe in detail the external facilities that interface with the MIDACS.

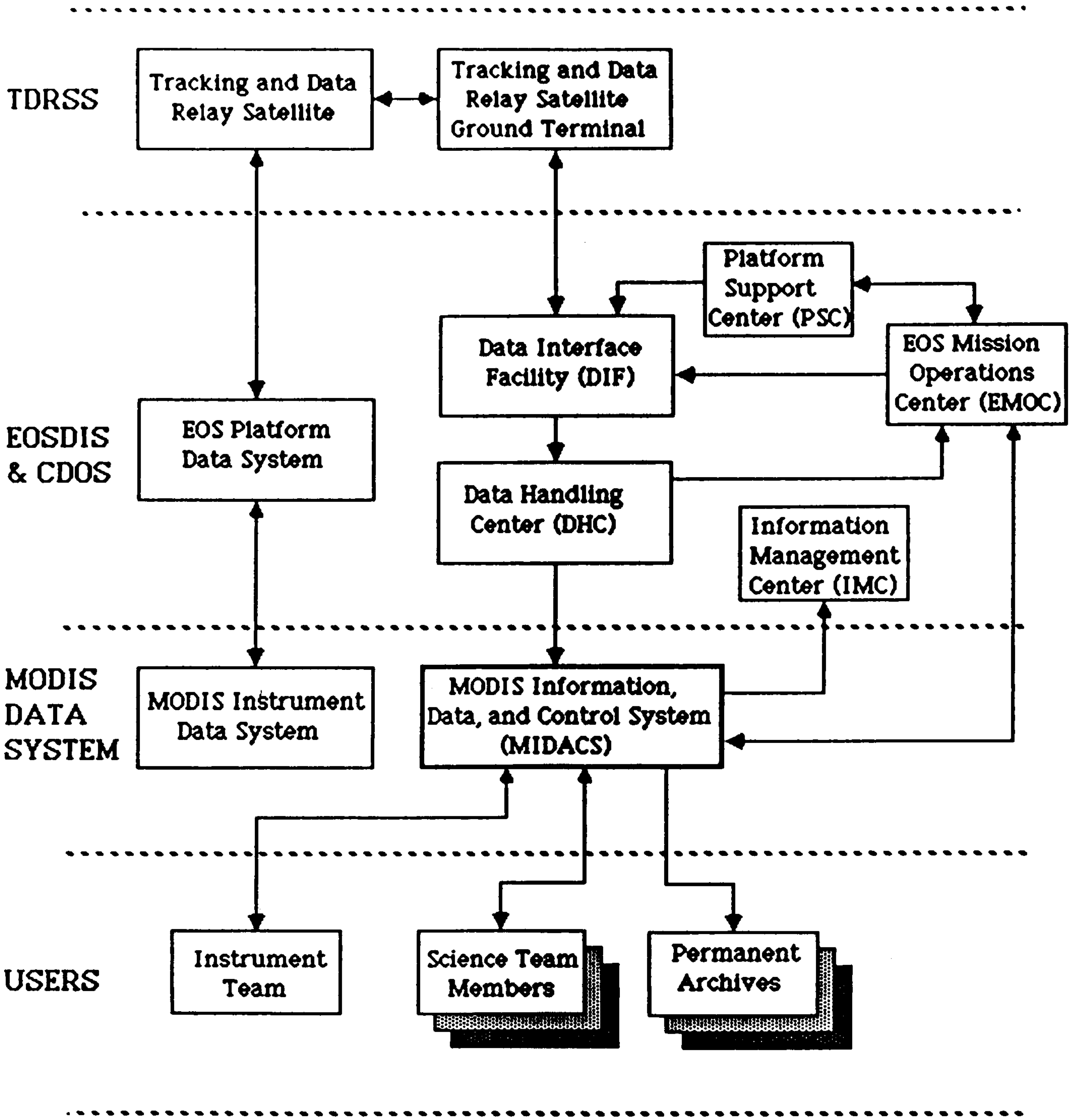

Figure 1. The MODIS Data System in the EosDIS Environment

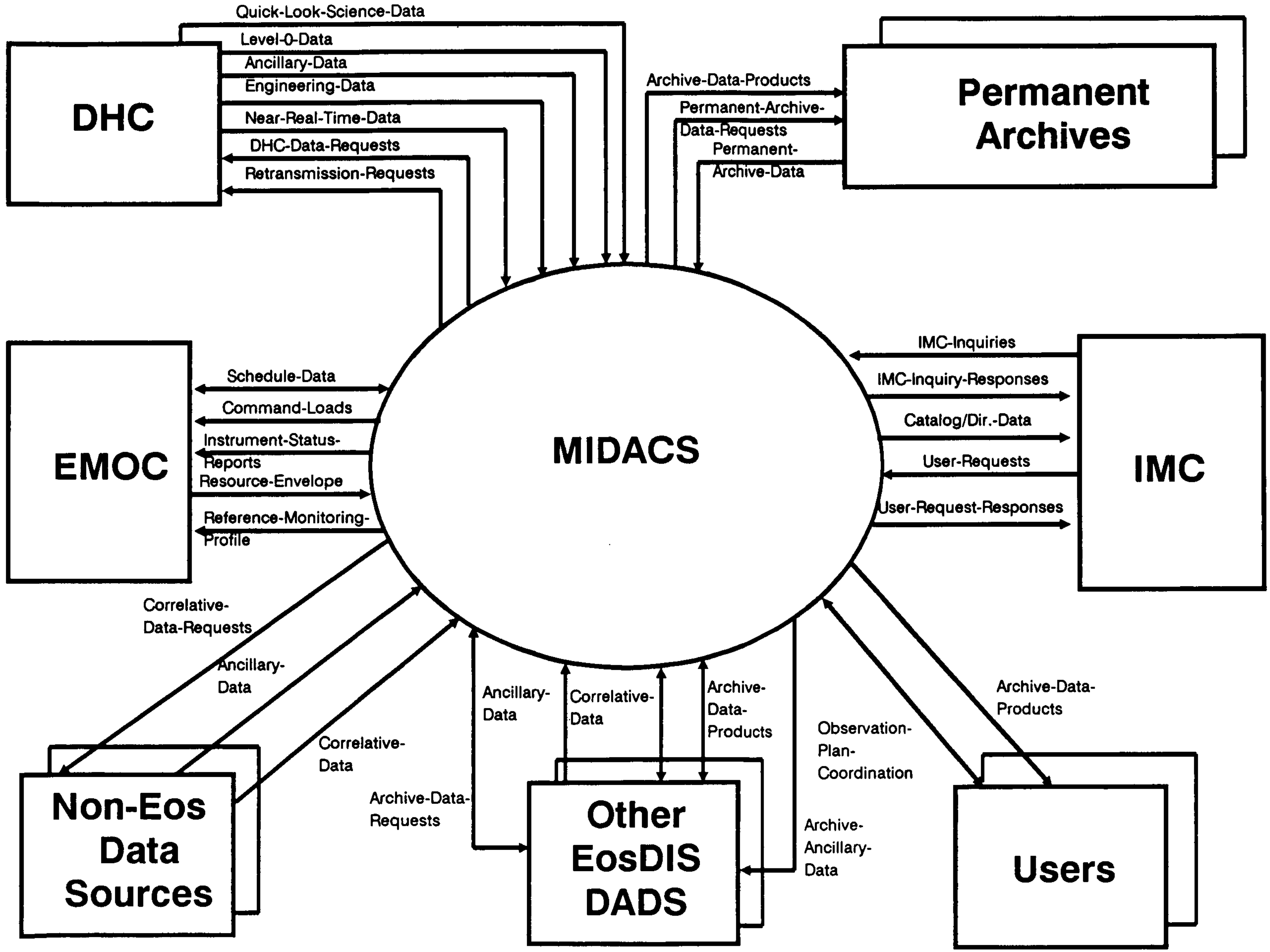

Figure 2. MIDACS Context Diagram

2.1.3.1 *EOS Mission Operations Center (EMOC)*

The EMOC will coordinate the operation of EOS instruments on the U.S. platforms and will provide the primary point of contact between the EOS mission and the Space Station Information System (SSIS) for mission operations. Located at GSFC, the EMOC will consist of a project team that includes the Project Operations Director (POD) and the Assistant Project Scientist (APS).

The EMOC will provide the EOS schedule based on the science plan from the Investigator Working Group (IWG), resource availability received from the Platform Support Center (PSC), and planning support information from the Flight Dynamics Facility (FDF). (A portion of platform resources may be reserved for NOAA.) The EMOC will not be responsible for scheduling NOAA operations but will coordinate with NOAA for the scheduling of potentially conflicting operations between NOAA instruments and MODIS. The sub-allocations of the remaining resources and guidelines for scheduling will be provided by the EMOC to the MODIS Instrument Control Center (ICC) for scheduling instrument operations. The EMOC will receive the schedule requests from the ICC, resolve conflicts between instruments, and provide a single request for platform resources to the PSC. This process will be iterated until a final conflict-free schedule is distributed to the ICC. The schedule is then stable but will be able to accommodate perturbations caused by unplanned changes in resource availability, anomalies, and/or Targets of Opportunity (TOO).

The EMOC will monitor operations by processing (and displaying) instrument status information received from the ICC and the ancillary data received from the Data Handling Center (DHC). If a safety problem is detected, the EMOC, the PSC, or the ICC can send a saving command sequence to the instrument. This will be a coordinated action. The EosDIS will monitor the data distribution systems in order to detect problems in delivering EOS data.

A log of EMOC operations (including commands received from the ICCs) will be maintained and archived. These archives, coordinated and managed by the EMOC, will be used to support future anomaly analysis and/or science data analysis. The EMOC will provide reports on EOS operations to the EOS project, and it will report the science plan implementation status to the IWG.

2.1.3.2 *Data Handling Center (DHC)*

The DHC will routinely perform Level-0 Processing (LZP) for all EOS payload data. The DHC is likely to be a distributed function whose location(s) and architecture have not been resolved, but these choices are internal to the Customer Data and Operations System (CDOS) project. As a backup to the Command and Data Acquisition (CDA) link, full resolution operational data will be routinely transmitted via the TDRSS through the Data Interface Facility (DIF) to the DHC as part of the downlink data stream. Some or all of these data may receive LZP to satisfy unique requirements of the research community.

At the DHC, Virtual Channel Data Units (VCDU) will be converted into constituent packets; data will be time ordered and, if necessary, reversed; the data will be organized into Level-0 data sets for temporary storage; payload engineering data packets and other designated high-priority data packets will be stripped off and forwarded to the MIDACS; and ancillary data support services will be performed. Ancillary data transformations (e.g., coordinate transformations) and calibrations may be made (if preferred standard computations are not available in the on-board ancillary packets) and enhanced ancillary data packets produced. These production and ancillary data sets will be made available to the MIDACS. Level-0 data will be forwarded to the MIDACS within 24 hours of observation in accordance with prearranged schedules and routing; however, near-real-time data supporting field experiments will be forwarded within six hours, perhaps without all LZP performed.

The DHC must also be able to detect, process, and route engineering and priority playback data to the appropriate user in a timely manner. Real-time engineering data are engineering/housekeeping data transmitted during a TDRSS contact period. The data will include both platform and payload information. They should be routed in a pass-through mode that minimizes delay to the MIDACS. Priority playback data consist of platform or payload engineering data and selected science data recorded on-board that are required in less than the normal turn around time from the DHC. Priority playback data are forwarded to the MIDACS.

The DHC will also be responsible for the quality control of ancillary data received from the platform. Ancillary data values will be checked against high and low limits and in coordination with the FDF; onboard orbit/attitude parameters will be validated by comparing these data with orbit and attitude reference profiles. The DHC will make all ancillary data available to the MIDACS, and it will store this information for a minimum of two years. The format of ancillary data and the checks to be performed will be developed by the Ancillary Data Support Working Group currently meeting at GSFC.

2.1.3.3 *Information Management Center (IMC)*

The Information Management Center (IMC) is treated in this report as an external interface. It will be the clearing house for all information about EOS data. This function will provide multi-user one-stop connectivity for EOS data information including directory, metadata, and catalog data, as well as access to actual data sets and browse data sets. The IMC would maintain cognizance over all data requests and will ensure their successful and timely fulfillment. It should be emphasized that only EOS catalog and metadata are stored at the IMC.

All EosDIS users will access the IMC via an EosDIS network interface. This feature must support connectivity with a variety of government and commercial networks as well as several communications protocols and a variety of user terminals. All of this must be accomplished while providing the user with a simple, "friendly" menu-driven interface protocol to allow him to request his desired information. All data request and response queries will be via this link; actual data set transfer will be directly from the data repository to the user.

A variety of catalogs/directories will be maintained on-line, ordered by date/time, instrument (including different channels/ resolutions/operating modes), environmental parameter, geographical location, feature detection, data location, etc. It is anticipated that most requests can be filled from this subsystem in an automatic fashion, with manual intervention available for unusual requests. Response time to a user should be timely, and will be limited by the search capability of the system. EosDIS will be unique in the environmental data world in its goal of making multi-discipline data available to a world-wide group of scientists. In order to do this effectively, a sophisticated data management system will be required with an ability to track the progress of all new EOS data every day as well as previously recorded and processed EOS data.

Request for data sets will be sent to the appropriate archive facility and status information received. The IMC will also feature an On-line Documentation Subsystem to support EosDIS requirements to:

a. Maintain on-line documentation containing information on EosDIS requirements, specifications, command loads, engineering data and diagnostics, test and calibration procedures, operations software algorithms, validation results, scientific papers and system operations procedures.

b. Monitor and report on program, platform and payload status.

Documentation and status information will be received from all elements of the EosDIS and maintained on-line for access by the users.

A final feature of the IMC will be a project billing and accounting function. Users desiring EOS data will need to establish an account with the IMC in order to obtain services, information, and data. The method of operating this feature will be determined at a later date.

2.1.3.4 *Tracking and Data Relay Satellite System (TDRSS)*

The TDRSS provides the uplink and downlink capability for the EOS platform. On the average, a platform should have access to the TDRSS for about one-third of its orbit. The MODIS data will be downlinked by the TDRSS to the White Sands Ground Terminal (WSGT) for routing to the MIDACS. Uplinking through TDRSS will be used to support commanding of the instrument. In order to support specific real-time instrument requirements and the timeliness requirements of certain field experiments, the TDRSS must be responsive to the MIDACS when scheduling access times.

2.1.3.5 *Data Interface Facility (DIF)*

The DIF provides data communication, data buffering, and data routing between the space network and ground data network.

2.1.3.6 *Platform Support Center (PSC)*

The PSC is a proposed GSFC facility under the CDOS that will provide mission control support for a variety of space programs at GSFC. The PSC will perform standard control center functions to monitor and control the platform operations. The PSC will be involved in the planning and scheduling functions for EOS payloads, as well as in all aspects of planning, scheduling, commanding, and telemetry monitoring of the platform core.

2.1.3.7 *Remote Users*

Users, except the MODIS science team leader and science team members, will interface with the MIDACS through the IMC. The MODIS science team members have the option of interfacing through the IMC, but they will also have direct contacts with each of the MIDACS elements.

2.1.3.8 *Long-Term Archives*

Several centers will serve as long-term storage areas for MODIS data. The data sets archived will contain high-level information. The National Space Science Data Center

(NSSDC) currently serves as a long-term archiving and distribution center for data obtained on NASA Space and Earth Science flight investigations and will provide for the long-term storage of atmospheric data. The NSSDC develops and performs a variety of services to enhance the scientific return in these missions. NOAA will provide for the long-term storage of oceanographic data. The EROS data center will provide long-term storage for land data.

2.2 FUNCTIONAL DESCRIPTION OF MIDACS

The following sections are a list of internal elements of MIDACS and the respective functions which support the MODIS instrument.

2.2.1 Instrument Support Terminal (IST)

The IST is essentially a workstation connected to the ICC. It gives the science team leader or designated team members by the team leader access to the engineering data or quick-look science subsets of the payload in order to support instrument integrity functions and/or to initiate commands and plans for specialized conditions.

2.2.2 Instrument Control Center (ICC)

This center is responsible for the ground control operation of the MODIS instrument on board the platform. It is assumed that there is one ICC dedicated to the MODIS instrument. The ICC will support the instrument planning, scheduling, commanding, and status monitoring of MODIS.

2.2.3 Team Member Computing Facility (TMCF)

A science team member will be responsible for the development and maintenance of the algorithms for the production of data sets. The TMCF will be a distributed network of project-provided computing resources to be used in the development and testing of algorithms, the production of special data sets, and the assessment of data quality including calibration, earth location, certification, and validation.

One of the network nodes will be located at the GSFC. Because MODIS will be a Goddard Facility Instrument, the GSFC TMCF is unique within TMCF in the following aspects:

a. Several MODIS science team members, each with their own computing facilities (e.g., workstations), will reside there.

b. The MODIS science team leader will be at this node.

c. The MODIS Calibration Support Team (CST) will have several workstations at this node.

d. A group of computer scientists at the GSFC node will aid MODIS science team members in making their computer codes more efficient and in compliance with EosDIS software standards. They will also develop programs of general utility to all MODIS science team members.

2.2.4 Central Data Handling Facility (CDHF)

The CDHF has the responsibility of receiving instrument data and generating standard products for the user at predetermined levels of processing. The levels of data to be produced include Level-1A (reversible to Level-0), Level-1B (calibrated and Earth-located radiances), Level-2 (geophysical parameters), Level-3 (gridded and averaged products), and Level-4 (scientific applications and comparisons to non-MODIS products).

2.2.5 Data Archive and Distribution System (DADS)

The DADS will provide for the storage, management, and distribution of processed data sets, catalogs, and directories for data supplied by the CDHF and others. It provides an interface to the users for distribution of requested products.

2.3 PERSONNEL AND OPERATIONS TEAMS IN THE MIDACS

This subsection defines six categories of personnel required for conducting mission operations in the MIDACS operations environment. They are:

a. MODIS science team and team leader
b. Instrument Operations Team (IOT)
c. MODIS CST
d. Product Support Analyst
e. System Operators
f. Data Clerks

These teams represent a wide range of job responsibility, technical expertise, and authority. In order to successfully accomplish the MODIS functions described in Section 2, a set of roles and responsibilities for each of the teams and interactions between them is presented. An additional discussion on the classification of science users is included in this section.

2.3.1 MODIS Science Team

The MODIS science team, under the direction of the MODIS science team leader, will be staffed by scientists having well-established expertise in the use of multispectral imagery to solve scientific problems related to the environment. They will be selected by NASA based upon the proposals they submitted in response to the NASA Announcement of Opportunity (AO) for EOS. This team has the following roles and responsibilities:

a. The science team is responsible for the development of algorithms for the generation of MODIS standard and special data products and the approved algorithms for generation of MODIS standard data products.

b. The science team participates in the certification of all standard products generated by algorithms used in standard MODIS software.

c. The science team provides quality assurance criteria for science products.

d. The science team provides documentation to science users regarding use of the instrument and interpretation of instrument data distributed through the DADS.

e. The science team coordinates science planning for use of the instrument, including routine operations and supporting field experiments.

f. The science team reviews calibrations performed by the MODIS CST.

g. The science team provides EOS project-approved guidelines, priorities, and science plans to the IOT to direct instrument scheduling and commanding.

h. The science team assists the EOS project in resolving conflicts in scheduling, not covered by guidelines provided to the operations team.

2.3.2 Instrument Operations Team

The IOT is responsible for ground control of the MODIS instrument and receives direction from the MODIS science team. The IOT will normally be resident at the ICC. This team has the following roles and responsibilities:

a. The IOT supports planning and scheduling functions using plans and guidelines of the science team and IWGs.

b. The IOT generates MODIS instrument command sequencing and command files.

c. The IOT provides routine monitoring of instrument operations (engineering and science) and ground-to-space link via DHC.

d. The IOT performs instrument anomaly detection and preliminary analysis for instrument safety. Safe the instrument, when required, per predefined procedures. Alert the MODIS science team and CST for anomaly resolution.

e. The IOT coordinates operations planning, scheduling, and commanding with the MODIS science team.

f. The IOT interacts with and provides necessary support to the EOS mission operations team at EMOC.

g. The IOT supports the MODIS science team and the EOS mission operations team at EMOC in coordinating multi-instrument operations.

2.3.3 MODIS Calibration Support Team

The MODIS CST is responsible for the characterization and calibration of the MODIS instruments. By characterizing the instruments, they ensure the health of MODIS and determine proper modes for its continued use. Through calibration, they allow for the correct processing of MODIS science data in the generation of higher-level data products. This team will include specialists with several different areas of expertise such as instrument engineers, physicists, and computer scientists. This document is intended to describe only those aspects of the team directly associated with data processing. The CST has the following roles and responsibilities:

a. The CST supports those aspects of calibration, both preflight and inflight, which lead to the generation of data products or calibration algorithms.

b. The CST generates MODIS calibration products ("calibration files") for use by the rest of MIDACS and the EOS community.

c. The CST develops and maintains standard software for production of MODIS Level-1 data.

d. The CST performs long-term trend analyses on the MODIS instrument.

e. The CST performs detailed instrument anomaly analyses and formulates appropriate responses.

f. The CST maintains calibration files and updates Data Quality Assessment (DQA) criteria.

g. The CST provides instrument engineering support to the MODIS science team.

2.3.4 Product Support Analysts

Product Support Analysts (PSAs) are responsible for routine product distribution and product archiving, ensuring the quality of products and the standard software used to generate these products. There may be product support analysts affiliated with the science team, the CDHF, the ICC, and the DADS, each having slightly different roles. In general, they have the following roles and responsibilities:

a. The PSAs document the state of all archived products.

b. The PSAs coordinate the generation and maintenance of directory, catalog, inventory, and bibliography for the product archive.

c. The PSAs ensure the quality of products as they are generated, based on quality control criteria defined for them.

d. The PSAs ensure the quality of ordered products before shipping to the users.

e. The PSAs provide consultation to science users regarding contents of the product archive.

f. The PSAs ensure the proper archiving of specialized MODIS science products received from all EOS investigators.

g. The PSAs perform maintenance, testing, and configuration control of all standard processing software.

h. The PSAs convert science team-provided algorithms to standard software for the production of standard MODIS data products.

2.3.5 System Operators

The system operators are responsible for the operation of computer systems (i.e., hardware, vendor-supplied software, and applications software) and the generation of products in the MIDACS facilities. They are affiliated with each facility, and their roles are facility-dependent. In general, they have the following roles and responsibilities:

a. The Systems Operators operate hardware and software elements in the system.

b. The Systems Operators monitor the health of hardware and software elements in the system.

c. The Systems Operators support preventive maintenance of the system.

d. The Systems Operators perform first-degree diagnostics in the event of system (hardware or software) anomaly.

e. The Systems Operators ensure the security of the computer systems.

f. The Systems Operators generate MODIS products using defined procedures and schedules.

2.3.6 Science Users

The MIDACS will serve the science community by responding to MODIS observation requests from science users and providing them with science products needed for their investigations. These science users, although not MODIS operations personnel, will interact with the MIDACS facilities and operations personnel. In general, science users are affiliated with universities or research agencies and have no intimate knowledge about the MODIS instrument. Although some may be multi-disciplinary, most will work in one scientific discipline.

The following science-users classification scheme may be useful in defining the priority of instrument observation requests, resources allocation, privileges and limitations, and turnaround time of product generation by the ground system:

a. MODIS science team members.

b. NASA-Sponsored EOS Investigators: Includes EOS Interdisciplinary Investigators and science team members for instruments other than MODIS.

c. Other NASA-Sponsored Science Users: Funded by NASA programs other than EOS.

d. NOAA-Sponsored Science Users.

e. Foreign-Sponsored EOS Investigators.

f. Other Science Users: Includes non-EOS foreign investigators, researchers of other U.S. government agencies (e.g., DoD), and other researchers.

2.3.7 Data Clerks

Data clerks will be affiliated with the DADS. They have the following roles and responsibilities:

a. Data clerks perform order desk functions. This includes managing electronic orders from the IMC.

b. Data clerks provide bookkeeping and accounting support to the IMC, to the degree necessary.

c. Data clerks follow-up on the generation of direct data products (e.g., CCTs, optical disks, photos), based on product orders.

d. Data clerks package and ship direct data products to science users, and report these actions to the IMC.

3. MIDACS OPERATIONS

The MIDACS is divided into two areas of responsibility: Instrument Operations and Data Operations. Instrument operations will be provided by the ICC and the IST. Data operations will be provided by the CDHF, the TMCF, and the DADS. Figure 3 presents the internal MIDACS functional allocation and internal data flows. The internal facilities of MIDACS and the respective functions which support the MODIS instrument can be summarized as follows.

Within the ICC, the IOT is responsible for the ground control and monitoring of the operation of the MODIS instrument. The IOT will support the instrument planning, scheduling, commanding, and status monitoring of the MODIS instrument.

The IST is essentially a workstation connected to the ICC. It gives the team leader access to the MODIS control and monitor database in order to support instrument integrity functions and to initiate commands and plans for specialized conditions.

The TMCF will be distributed and will support the development and maintenance of the algorithms for the production of calibration and scientific data sets. The TMCF will consist of project-provided computing resources at team member locations to be used in the development and testing of algorithms, the production of specialized data sets, and the assessment of data quality. Because MODIS is a GSFC facility instrument, the largest node of the distributed TMCF will be at GSFC and will have a primary responsibility for all TMCF functions.

The CDHF has the responsibility of receiving instrument data, and processing and generating standard products for the user at predetermined processed levels.

The DADS will provide for the storage and management of processed MODIS data sets, catalogs, and directories for archival data processed by the MIDACS elements. It provides an IMC interface to the user for distribution of requested products and archiving of data to a permanent archive.

This section is divided into six subsections which provide detailed discussions of the concepts for each functional area. These areas cover: planning and scheduling; control and monitoring; data acquisition and production; calibration and validation operations; archive, catalog, and distribution; and user access operations. The facilities discussed above may, for certain operations concepts, sponsor several functional areas.

3.1 PLANNING AND SCHEDULING OPERATIONS CONCEPT

This MIDACS Operations Concept is derived from the information contained in references a through d. As an EosDIS unique element, the MIDACS must support the planning and scheduling of the MODIS instrument to provide the routine production of scientific products derived from its data. The routine production of MODIS data products reflects an overall, coordinated scientific plan for the EOS program. The development and maintenance of this plan is the responsibility of various working groups whose roles will be described below.

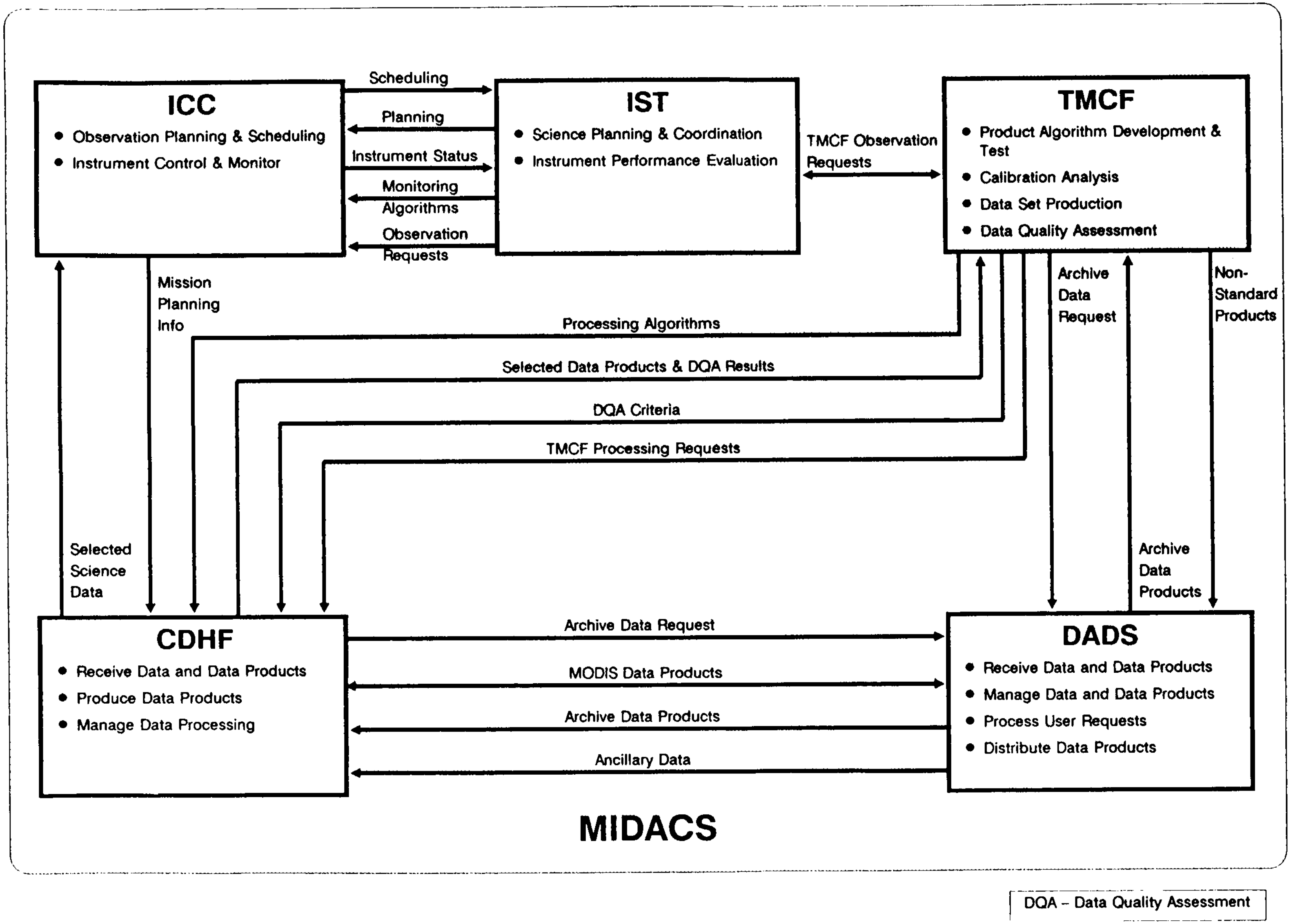

Figure 3. MIDACS Element Functional Allocation Diagram

3.1.1 Programmatic Coordination

The International Coordination Working Group (ICWG) will provide programmatic coordination of high-level policy and science consultation and guidance for the international EOS mission on all science-related long-range mission objectives. It will consist of one to three representatives from each of the major EOS partners. It will recommend payload responsibility and platform assignment for EOS, and it may also: establish overall objectives, assist in developing scientific requirements, assist in definition of international scientific platform data interfaces, and participate in the EOS project reviews to coordinate scientific requirements and mission decisions relating to international scientific objectives. It is anticipated that this group will meet infrequently.

3.1.2 Science Planning Organizations

3.1.2.1 *International Investigator Working Group (IIWG)*

The organization of the international scientific efforts of EOS is centered around the IIWG, formed to coordinate research and operations among the EOS Polar Platforms.

The IIWG is the primary science element of the international EOS mission and will formulate the international observing policy and overall science objectives for all EOS platform activities. They will also develop science plans to accommodate special windows of opportunity. The IIWG will be divided into four subgroups (IWGs), one for each platform. The IIWG will meet once a year during operations to discuss the scientific results of the mission and review and coordinate future investigations and related observational sequences.

3.1.2.2 *Investigator Working Group (IWG)*

There will be an IWG for each of the Polar Platforms (two for NASA, one each for ESA and Japan). The NASA IWGs are the primary science elements of the NASA EOS Project. They play the leading role in the overall optimization of the science return from the two U.S. platforms. These activities are coordinated with the IIWG. The NASA IWGs are composed of the following members:

a. EOS Project Scientist (Chairman)
b. Principal Investigators from that platform
c. Team Leaders from that platform
d. Program/Deputy Program Scientist (ex officio)

The IWG receives policy, guidelines, and overall science objectives from the IIWG. The IWG will provide high-level science mission guidance to the EOS Project, establish science mission priorities and develop the long term detailed science plan (updated as required), and evaluate proposals for data observations submitted to the Science Teams. The IWG will meet on a regular basis for exchange of inter-experiment information, coordination of investigations, review of requests for specific observational sequences, and review of scientific results of the mission. It is the MODIS team leader, a member of the IWG, who provides the science plan and coordinated MODIS observation requests to the MIDACS for planning and scheduling.

3.1.2.3 *MODIS Science Team*

The MODIS science team consists of selected scientists who are interested in investigations which make use of the MODIS Research Facility Instrument being developed by the GSFC for the EOS Project. The science team will contribute substantially to guiding its design, development, test, calibration, operation, data reduction, and algorithm development.

The science team will consist of team members and will be organized under the direction of a team leader. The science team will plan and conduct investigations, participate in final instrument definition, development, test, calibration and operation, and develop algorithms for the reduction, analysis, and interpretation of the data, and publish results. The science team will have access to the IST of the MIDACS from which to participate in instrument planning and scheduling, instrument monitoring and problem resolution. The science team will also have available the TMCF of the MIDACS to develop and test algorithms, analyze MODIS data, and produce special data sets. The science team leader and members can access the DADS either directly or through the IMC. Observation requests from nonscience team members will be processed through the IMC for authorization by the science team leader.

3.1.3 MIDACS Instrument Operations

The MODIS instrument complement of MODIS-T and MODIS-N will routinely acquire global or near-global data every day. To accommodate this acquisition, the instrument must maintain maximum duty cycles. The data routinely taken by MODIS-N will have a 100% duty cycle. The data will consist of digital counts from 15 thermal-infrared channels at all times and digital counts from 25 reflected-energy channels when scanning the illuminated portion of the Earth (approximately 50% of the orbit). MODIS-T will routinely take data on a 100% duty cycle during the daytime only. MODIS-T data consist of digital counts from 64 reflected-energy channels when scanning the illuminated portion of the Earth. MODIS-N will have a simple schedule operation due to its duty cycle and constant scan operation, while MODIS-T has an added command operation of tilt forward or backward with respect to the orbital velocity while scanning. The routine planning and scheduling of MODIS-N and MODIS-T should be dynamic in response to platform and communication changes, instrument anomalies, or observation request for TOO, or activities unknown at this time.

In addition to these routine instrument operations to collect science data, instrument calibration will also be performed to ensure accurate observations. Calibration of the MODIS-N and -T instruments will be maintained throughout the mission lifetime. Operation of the instrument to accommodate calibration may impact collection of science observation data and routine planning and scheduling procedures. These calibration operations include, but are not limited to, instrument operations to determine accuracy of radiometric measurements, detector normalization, and long-term stability. Instrument operations to monitor calibration sources can be included as part of an observation, or may be dependent upon internal or external calibration sources.

The typical instrument operations concept begins with the science planning process. The MODIS science team leader is a member of the IWG and it is through this interface that changes to the MODIS Science Plan are conveyed to the MIDACS. The MODIS science plan and changes to it are made via the EMOC. Special observation requests or changes to the science plan are sent via the IST interface by the MODIS team members. A special observation request, as opposed to an outright change to the science plan, may be just a one-time detector calibration sequence. It is the science team leader's responsibility to coordinate and prioritize changes or additions to the MODIS science plan. The resultant information is conveyed to the ICC via the IST as an observation request (see Section 3.1.4).

Upon receipt of the observation request, the ICC invokes its planning and scheduling apparatus to publish a candidate instrument operational schedule to the EMOC. There, the EMOC integrates the MODIS schedule with schedules from all other EOS ICCs. Ultimately, a final and approved MODIS schedule is sent back to the ICC, whereupon a MODIS command load is released to the EMOC for forwarding to the space segment.

Once the MODIS commands are implemented, the command verifications are sent to the ground via TDRSS either directly or later during a tape recorder playback. It is at this time that the ICC/IST Control and Monitor functions of limit checks, caution and alarms, command verification, and instrument trending analyses take place. A more detailed instrument operations concept is provided in the following subsections.

A high level diagram, Figure 4, presents the ICC and IST elements involved in instrument operations. The DHC will receive MODIS engineering data and science data and provide it to the ICC for monitoring purposes. The IST will provide a conduit for the science team leader to request observations and commands, send monitoring algorithms, and to receive information about instrument performance and the feasibility of any observation request. As a possible alternate path, the CDHF may provide selected science data to the ICC for monitoring of the instrument detectors and other science-related instrument performance indicators. The ICC will interface with the EMOC for planning and scheduling operations and to transmit command loads to the MODIS instrument.

The IST will be used by the MODIS team leader to remotely access the ICC and potentially to coordinate observation plans with users and science team members. Potential functions of the IST include providing science planning and coordination and monitoring instrument performance.

3.1.4 Observation Requests

Science team members and other users will generate observation requests for their planned science investigations. The observation request may contain the following information:

Geophysical/Environmental Information:

- Observation Times
- Target Location
- Cloud Cover Parameters
- Surface Types

Science Information:

- Science Objective
- Science Products
- Monitoring Requests

Instrument Information:

- Spectral Band Selection
- Tilt (MODIS-T)
- Gain
- Calibration
- On-Board Processing (reduced resolution)

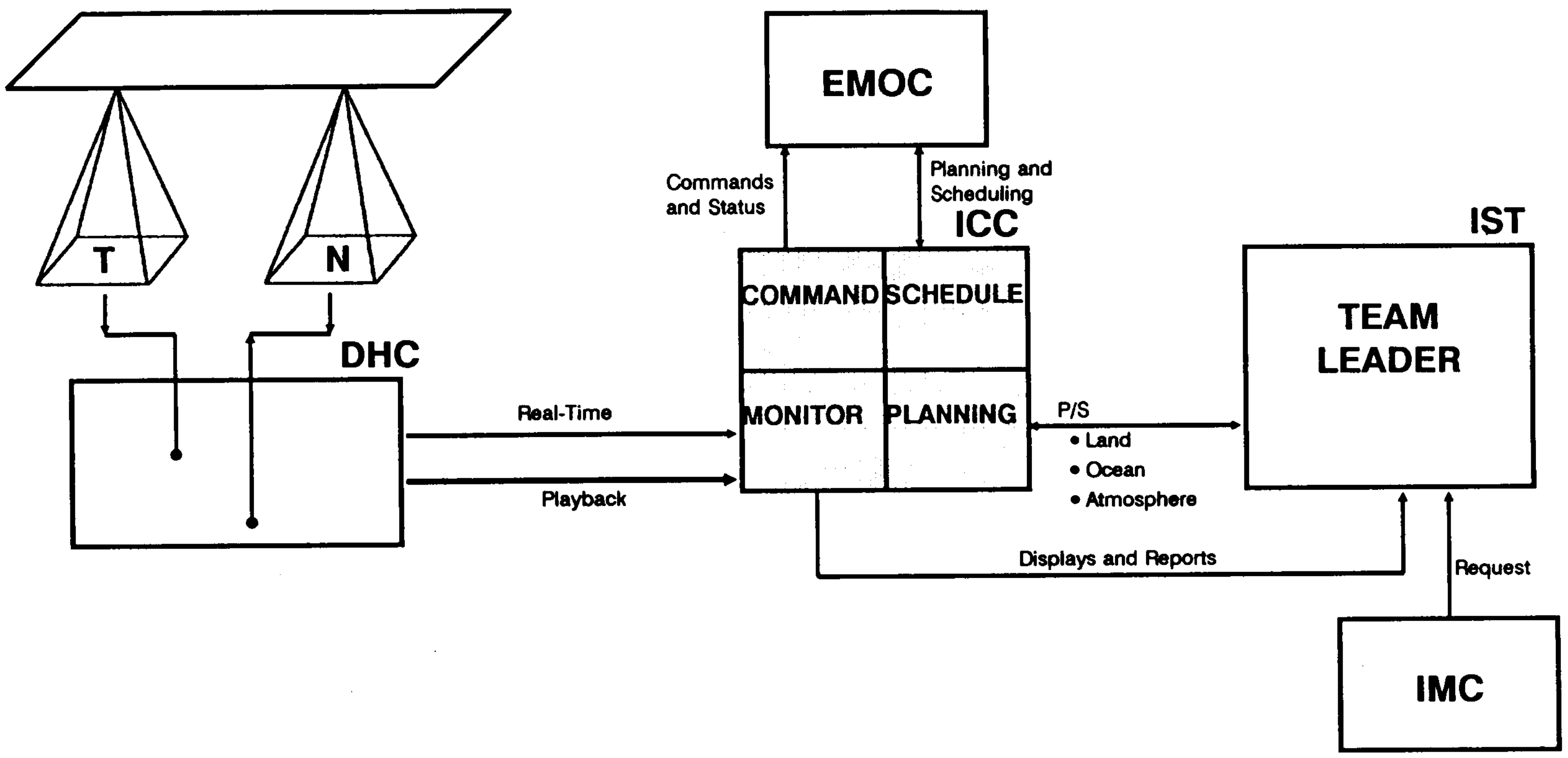

Figure 4. ICC/IST Operations Interface

Observation requests may also include information for the scheduling of observation data for support of field experiments, possibly at distributed TMCF locations. Field experiments may require calibrated radiances from 15 MODIS-N and/or -T channels at specific target locations, as well as higher-level products, that first must be processed by the CDHF in near-real-time (within three to eight hours of the observation). The field experiment information will then be incorporated into the baseline observation requests for planning and scheduling.

An observation request may be originated in two ways, either by a science team member or a researcher who is not a member of the science team. In the latter case, the researcher will enter an observation request through the IMC. The IMC will provide the appropriate communication service for transmission of the request to the IST for approval by the science team leader before notifying the ICC of the request. For a science team member-generated observation request, the science team leader will have the responsibility for transmitting the request via the IST to the ICC. In either case, the science team leader will have established the guidelines for the submittal of observation requests to the ICC and may be involved only by exception or conflict. A standard observation request format will be agreed upon for delivery of observation requests.

3.1.5 Planning and Scheduling Operations

The IOT will be responsible for MODIS operations, including the equipment and personnel necessary for planning and scheduling, of the MODIS instrument. In the context of a control center environment, the activities associated with the transformation of a requested sequence of space-segment events into an integrated schedule of space (and possibly ground) segment events is commonly referred to as planning and scheduling. A routine event may enter the planning and scheduling process about a month (see scenario) ahead of the event time. This event undergoes the coordination, authorization, and approval process. At about one week ahead of event time, the event is typically considered scheduled.

The planning process takes high-level observation requests and generates a candidate schedule for instrument operation. This process is completed about one month prior to command loading. The scheduling process continues for approximately three weeks and is iterated with the EMOC until approval about one week prior to command loading.
The scheduling process can be divided into three areas of operations:

a. Initial Schedule Operations
b. Conflict Resolution
c. Command Sequence and Mission Plan Generation

The input of the scheduling process will contain the predicted platform orbit information from the EMOC, a set of guidelines for scheduling, and allocated operations envelopes for each instrument. Output of the scheduling process will be the initial schedule that is sent to the EMOC for approval. Scheduling information will also be sent to the science team leader via the IST.

To the extent that the EMOC will provide an operations envelope to the IOT for use in scheduling MODIS observations, the IOT will need the capability to model the instrument operations at the ICC. It will be the science team leader's responsibility to convey the appropriate modeling parameters. As the performance of the instrument becomes better known, the science team leader will provide the IOT, via the IST, with changes to any monitoring algorithms and instrument models for improved monitoring capabilities.

3.1.5.1 *Initial Schedule Operations*

Science planning and coordination involves receiving observation planning information in the form of Science Plan objectives from the IWG, special observation requests which were derived from external users and MODIS team members, and scheduling displays and status reports. This information is all coordinated, prioritized, and integrated into an observation request for transmittal to the ICC.

Figure 5 shows the operations involved in planning and scheduling and introduces the concept of a simulator for this purpose. Observation requests are passed through an interface to convert the request to a form usable by the ICC simulator. These requests are checked against environmental models (orbit, attitude, Sun, and scene) to determine the feasibility of the request (such as orbital geometry and observation data for support of a field experiment). After passing this check, the instrument utilization for the request is modeled to determine the required operations allocation to perform the observation. The instrument resource requirements are modeled to the extent that the operations envelope is allocated by the EMOC. Possible MODIS resources may be a combination of power, thermal, LAN usage, tape recorder usage, instrument tilt and mode of operation, and attitude. These resources are dynamic and require constant monitoring due to impacts by other instruments (e.g., HIRIS on/off) and platform or TDRSS activity.

A check of these requirements against the operations envelope is made. If either of these checks result in violation of the allocated resources, the IOT will inform the science team leader, via the IST, of the violation. A candidate schedule request is generated if no violations are found and is sent to the EMOC for approval. The candidate schedule consists of optimized instrument sequences, predicted instrument resource utilization, predicted instrument performance, and space network scheduling information. Updates can be made up to one week before command upload to cover environmental and space network changes. All scheduling information is sent to the team leader via the IST.

3.1.5.2 *Conflict Resolution*

Once a schedule is submitted to EMOC, the EMOC will merge the MODIS schedule information with other instrument schedules to identify conflicts in platform resource utilization and space network scheduling times. The EMOC will also check the resource requirements of the instrument against the operations allocation and guidelines of the original planning input to the ICC. Conflicts may be caused by differences in requirements for individual instruments necessary for scientific objectives, operating visible channels at night, by conflicts between science goals and system maintenance or communication schedules, by anomalous behavior of instruments or systems, or by real-time requirements. In the case where conflicts exist, the EMOC will send the ICC an iterated schedule possibly with changes to the available resources for MODIS. These changes may involve rejection of the request or rescheduling TDRSS contacts. In any case, the EMOC and/or the IOT will notify the team leader of conflicts to be resolved by the science team. After receiving changes by the science team leader, the process of modeling the MODIS instrument is again performed and a new schedule request is sent to the EMOC. This iteration process will continue until an approved MODIS schedule is resolved. If conflicts are not present, the EMOC will send an approved MODIS schedule to the ICC, as shown in Figure 5.

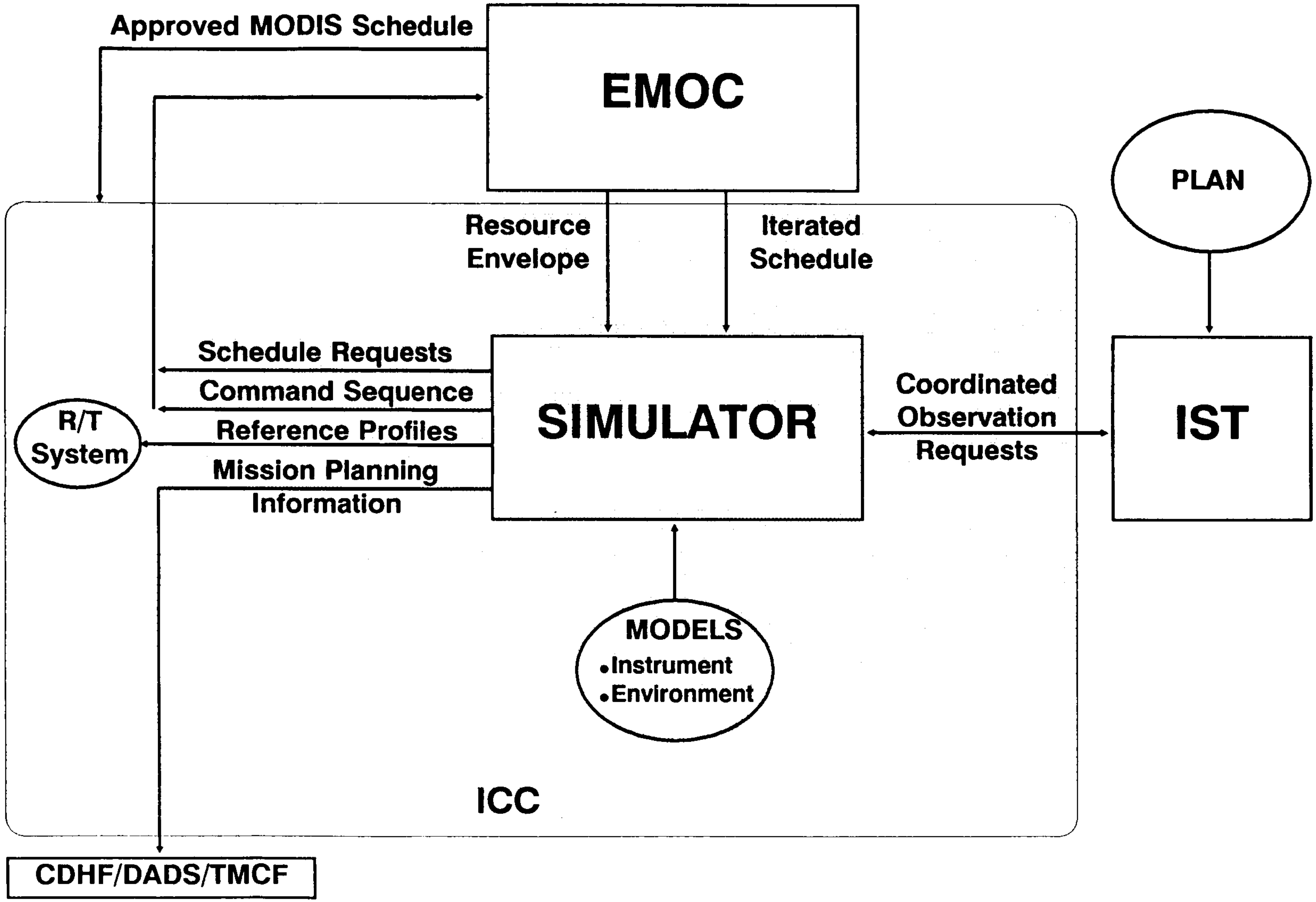

Figure 5. ICC Planning and Scheduling Operations Concept

3.1.5.3 *Command Sequence and Mission Plan Generation*

Once a schedule has been resolved through iteration with the EMOC and is approved, the IOT will generate a command sequence and mission planning information. The command sequence details the command events for a given time period, still in a human readable format, for input to the command generation process. These processes are completed approximately two weeks before commands are uploaded to the platform. In addition, the ICC will generate reference monitoring profiles and mission planning information that will be used by the ICC or other ground elements for monitoring instrument performance and scheduling data production. The reference monitoring profiles will contain the instrument parameter values expected in the downlinked engineering telemetry and will be used as input to the ICC's monitoring function. The mission plan will be used by the CDHF as an aid in checking input data and in generating a processing schedule.

Mission planning information in the form of data requests will also be sent to the DHC for scheduling the receipt and transmittal to the CDHF or ICC of real-time or near-real-time data for monitoring and field experiment supporting use.

3.2 CONTROL AND MONITORING OPERATIONS CONCEPT

The MIDACS, as an EosDIS-unique element, must sustain and maintain the control of the MODIS instrument in support of the coordinated science plan. To satisfy these support requirements, the IOT at the ICC will provide the control and monitoring functions. Control refers to the translation of schedules into command loads required by the MODIS instrument and the uplinking of these command loads. Monitoring is the process of reviewing MODIS engineering and science data to determine the current MODIS operational status.

3.2.1 Command Load Operations

Command load operations begin at least two weeks before uploading of commands. Figure 6 presents the command operations concept of the ICC. The commanding function in the ICC will accommodate the automated command sequences described in the previous section as well as manually generated commands. The manual command generator will accommodate a specific command request from the IOT supervisor or from the team leader in the IST. It is felt that, up to the command validator, the commands will take the form of a functional descriptor (e.g., ALL VIS CH OFF) with comments. The command validator will check to see that the input command is an authorized MODIS command. From there, the command is sent to the command translator. The command translator converts validated commands into a serial bit stream. Headers are appended containing information for EMOC, MODIS subsystem addresses, and possibly command load verification information. The transmit function will await control authority before being forwarded to the EMOC. If the translation of the commands is properly executed, then control authority is given and the command load goes out. It is felt that the entire process will be automated and that supervisory intervention may only be needed to resolve a failed command comparison or to issue a manual command request.

3.2.1.1 *Emergency Commands*

An emergency command situation may be discovered by the IOT using the ICC monitoring function and may be in response to a need to safe the instrument due to anomalous platform or instrument conditions, a request by EMOC, or the MODIS science instrument team. If the MODIS instrument exceeds its operational envelope, the on-board computer of the flight data system may be authorized to independently safe the instrument. It

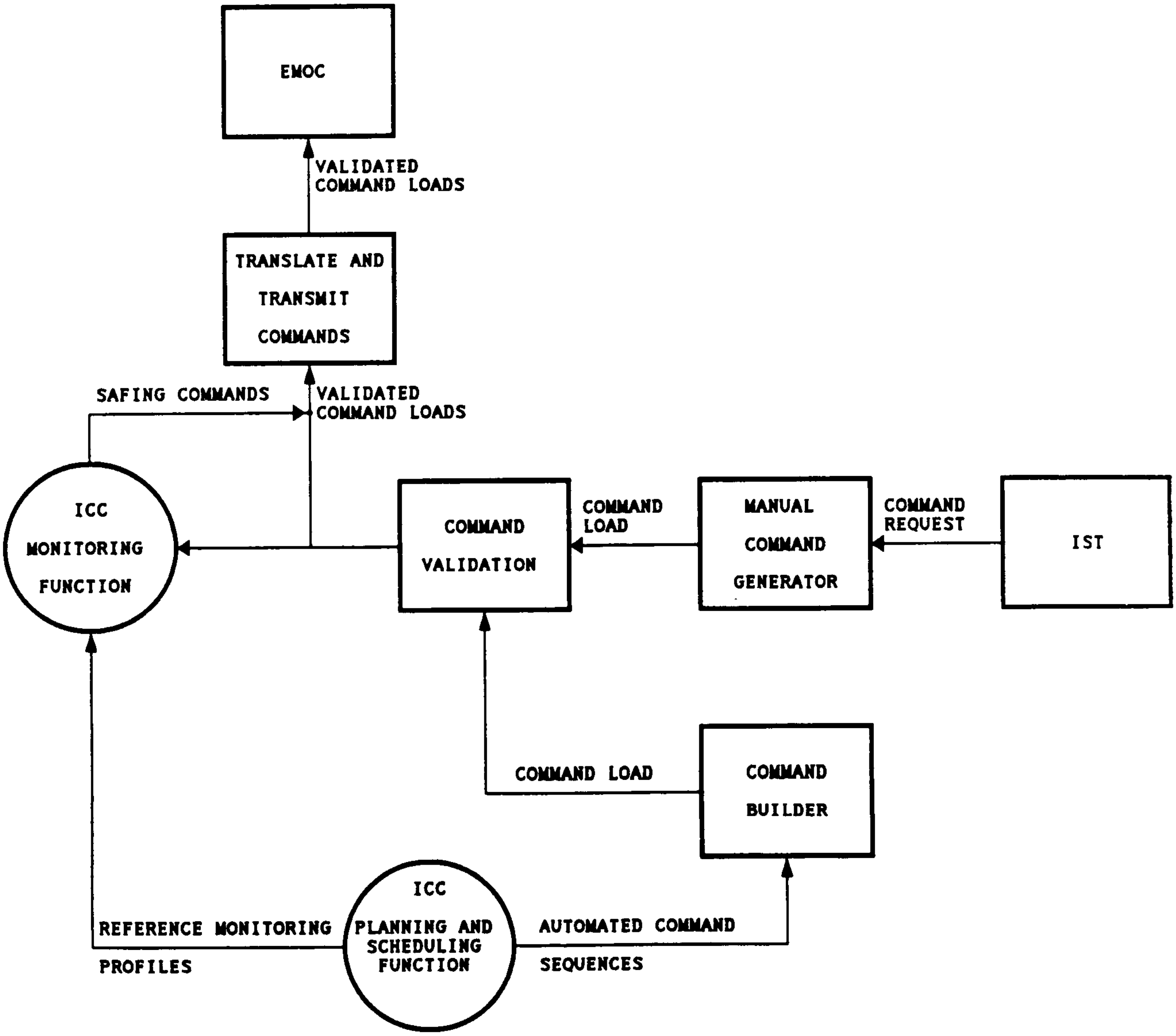

Figure 6. Commanding Operations Concept

will then be the responsibility of the IOT and the science team to determine and correct the anomalous condition. Most emergency command situations (e.g., instrument safing) will have been anticipated and critical command loads pre-generated and uplinked for storage on board. They can also be transmitted from the ground during a TDRSS contact to facilitate a rapid response. The pre-generation of commands will be an on-going process. Note that emergency commands have a double layer of control authority before release by the ICC; an authorized safing command load must still await control authority before being released.

3.2.1.2 *Real-Time Commanding*

Real-time commanding will be done in response to anomalous instrument behavior. A string of command loads will be generated and uploaded to the instrument to correct the anomaly. Real-time commands will still undergo validation at the ICC and EMOC before uploading.

Note that any command loads released from the ICC commanding function are included in the reference monitoring profile for use by the monitoring function for command verification.

3.2.1.3 *Target of Opportunity (TOO) Commanding*

The TOOs can be thought of as updates to the approved schedule and can be implemented as an update to a schedule or as a real-time command upload. The IOT will respond in an appropriate time line for this type of commanding. Again, the commands may be pregenerated to anticipated cases.

3.2.2 Monitoring Operations

Figure 7 shows the monitoring operations concept at the ICC. MODIS instrument operations will be monitored at the ICC by processing and displaying telemetry data that may include combinations of instrument engineering data, science data, and ancillary data using multiple downlink interfaces.

3.2.2.1 *Monitoring of Engineering Data*

The monitoring function includes checks on the calibration, power and thermal loads, data generation process, and other engineering parameters required to ensure proper operation of the MODIS instrument. The checks will be made as a comparison to the reference profile generated in the planning and scheduling or commanding function. Cautions and alarms may be generated for display. This process will also detect real-time problems and verify proper execution of the command loads sent to the MODIS. If an anomaly occurs, commands may be issued in real-time to correct the problem.

Engineering data will be retained at the ICC for a TBD time to analyze subtle trends or problems such as calibration drift, thermal heating, etc. Engineering data will then be forwarded to the EMOC and/or DADS for long-term retention. All ICC engineering cautions and alarms, command verifications, instrument status, scheduling status and trending analyses will be available to the science team leader via the IST. The team leader (or his delegate) will use these ICC displays, status reports, and database inputs as well as science data analysis which is available in the ICC and product monitoring from MODIS science team members to thoroughly analyze the MODIS performance. In addition to the observation requests discussed earlier, the science team leader may also send

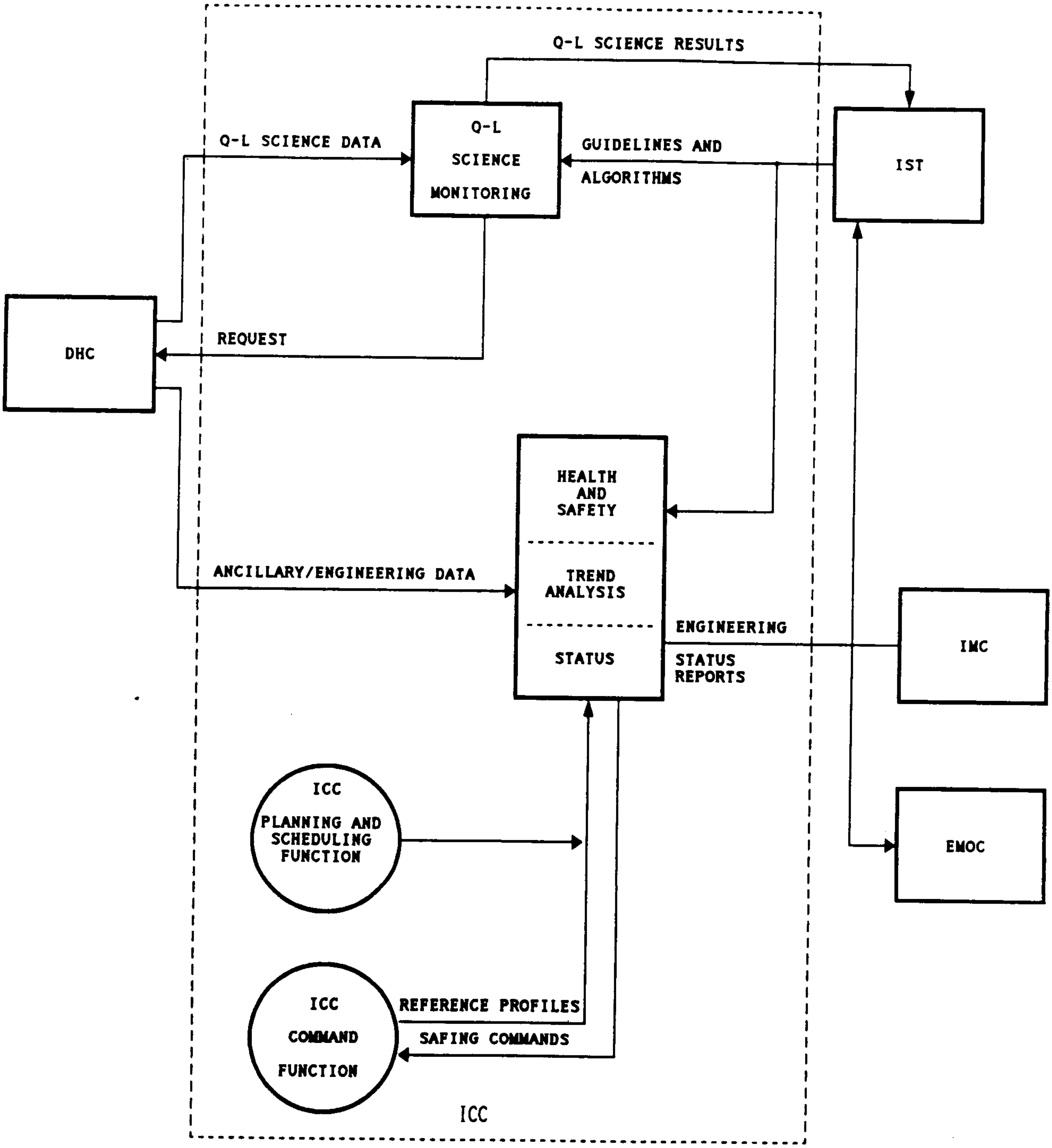

Figure 7. Monitoring Operations Concept

specific command requests to the ICC for conversion to a command load for uplink at an agreed upon time.

3.2.2.2 *Monitoring of Science Data*

There is a MODIS Level-I Requirement stating that the data system shall monitor subsampled science data in near-real-time to assist in the determination of correct instrument operation and data return.

The IOT may also perform analysis of selected science data when required to support instrument operations, instrument performance evaluation, and possibly field experiments. It is assumed at this time that the MIDACS will receive 100% of the science data directly from the DHC in a near-real-time mode of operation. The MIDACS will then sort, buffer, select the bands to be monitored in near-real-time, process the selected science data to a requested level, and store monitored data for further analysis and display in the ICC. Each of the MODIS instruments will be monitored separately on a workstation located in the ICC. The monitored science data will be used to evaluate the behavior of the instrument in terms of science collection.

3.3 DATA ACQUISITION AND PROCESSING OPERATIONS CONCEPT

There is a subtle difference between the terms "acquisition" and "reception." In the case of MODIS-N, the 100% duty cycle implies that the instrument data will be received by the ground data system without any required active involvement. In the case of HIRIS, no data will be taken unless a data acquisition request is generated. MODIS-T offers somewhat of a compromise, as the instrument retains a 100% (daytime) duty cycle, but takes data at different tilt angles upon request. We use the term "acquisition" here, recognizing that it describes a more passive role for the data system than that involved with the HIRIS ground data system.

This section presents a high-level concept of operations for the data acquisition and production of MODIS data at the CDHF. The strategy for the routine generation of standard Level-1 through Level-4 data products within the MIDACS, and specifically the CDHF, is driven by a number of functional and performance requirements. The sources of these requirements and related constraints include the MODIS/HIRIS Level-I Requirements Document, the MIDACS Functional Requirements Document, the MIDACS Levels-1 through -4 Processing Operations Concept, and other EosDIS and scientific documentation.

A context diagram showing the CDHF interfaces with other EosDIS elements is given in Figure 8. The primary input to the CDHF is Level-0 and ancillary data received from the DHC. The processing within the CDHF can be broken into three separate subfunctions: receive data, manage processing, and produce MODIS data products.
Here we consider the generation of standard MODIS data products within the CDHF as a part of EosDIS. The MODIS CDHF is responsible for:

a. Simultaneously generating MODIS standard products at Levels-1A, -1B, -2, -3, and -4.

b. Supporting field experiments and the observation of targets of opportunity through the generation of near-real-time products.

c. Reprocessing standard products at a rate of at least twice the original rate.

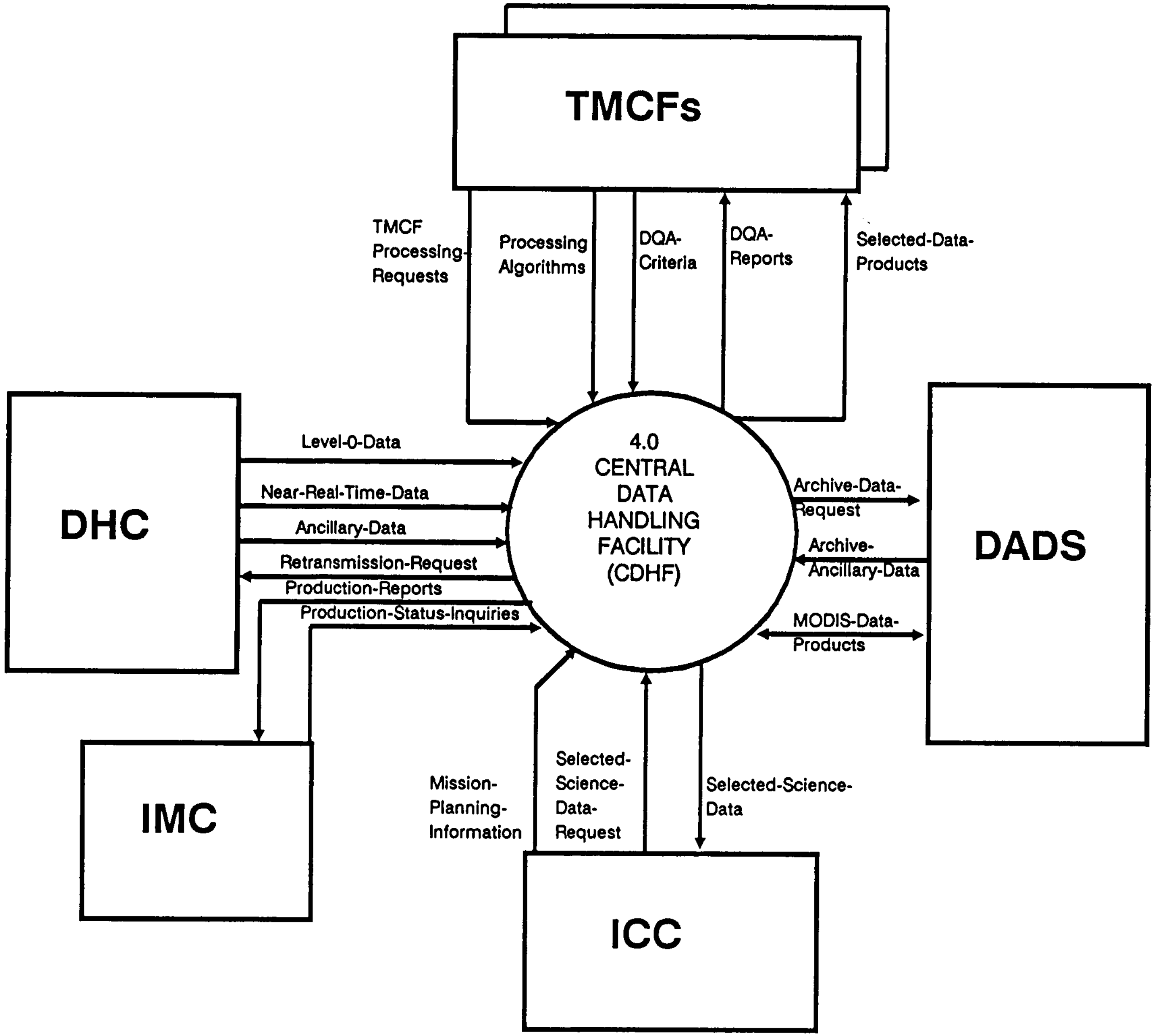

Figure 8. The CDHF Context Diagram

d. Supporting (in some not yet fully determined manner) algorithm developmental activities in their final stages prior to integration, perhaps in the form of special processing requests.

The CDHF will, as a part of its processing of 1, 2, and 3 above, routinely generate the corresponding browse data and metadata. The requirements constraining these activities (and others, such as routine maintenance) will be met jointly and, in doing so, it is not expected that the resources in the CDHF will be utilized beyond a level of 50% to 70%.

3.3.1 Receive Data

The receive data function accounts for data packets received from the DHC and generates received data ledger information that is compared to data timelines derived from mission planning information from the ICC. Missing data are requested to be retransmitted, and data are catalogued, stored, and made available for further processing.

3.3.1.1 *Priority Data Types*

Two types of priority data are available from the DHC. During the time when direct TDRSS contact is maintained, engineering data may be sent from the platform to the ground in real-time without the necessity of first recording the data on the onboard tape recorder. These data may be given priority handling at each of the CDOS ground processing nodes (DIF and DHC), so that these data are available essentially in real-time at the output of the DHC. The other type of priority data supported by the CDOS is priority playback. In this mode, the recorded data are given priority handling identical to that given real-time data once the data are retrieved from the onboard recorder. Essentially, these data have been delayed only by the time that elapsed between the recording and playback of the data.

The near-real-time processing in the CDHF can be applied to either of these CDOS data types. The switch to the near real-time mode occurs under the control of the manage processing function and may be applied to any of the processing capabilities supported by the produce MODIS data products function. The method that the CDOS will use to recognize priority data has not yet been defined. Presumably, near real-time processing in the CDHF can be initiated by the same control mechanism used to initiate priority handling within the CDOS. Except for possible missing data segments or "holes" in the received data, data that are received under priority handling are identical to that received using routine handling procedures. Since a request for retransmission of data would of necessity involve a delay while tapes are repositioned to obtain the required data, the priority handling mode does not necessarily support retransmission requests. Systems receiving priority data are each individually responsible for providing appropriate system responses to missing data segments. Except for effects resulting from missing data segments, the CDHF products generated in the near real-time mode are identical to those generated in routine processing.

3.3.2 Manage Processing and Handle Data

The manage processing function consists of data management and processing control functions needed to produce MODIS data products. Processing requests, new or modified processing algorithms, or modified DQA criteria are received from the TMCF and implemented through this function. If previously processed data products must be retrieved for use as inputs to higher-level processing, data requests are generated, and requested data is received, and managed. MODIS data products and archive ancillary data are sent to the DADS. DQA reports and selected data products are sent to the

TMCF, and production status reports are forwarded to the IMC. The manage processing function will be extended in some length in Section 3.3.3.4, Processing Strategy.

3.3.3 Produce MODIS Data Products

The generation of Level-1 through -4 data products, near-real-time data products, and browse data products are accomplished under the produce MODIS data products subfunction.

3.3.3.1 *Level-1 Processing Operations Concept*

MODIS Level-1 data processing takes place in the CDHF and involves the transformation of Level-0 data received from the DHC into Level-1A and -1B data products. The Level-1 processing operations concept presented below is based upon the Level-1 data product requirements. This concept consists of a description of the steps involved in Level-1A and -1B processing.

There may be two Level-1 MODIS standard products: Level-1A and Level-1B. The 1A product will, by definition, be reversible to Level-0. As such, no science or ancillary information will have been lost in its generation. The primary uses of 1A data will be: (1) to expedite the processing of higher-level MODIS data and (2) as an archive resource to permit possible future reprocessing of MODIS data. The 1A data will also be used by the CST for the maintenance of the MODIS calibrations. The Level-1B product will be derived solely from the Level-1A data and will no longer be reversible to Level-0. Most of the instrument and platform ancillary data will not be required at higher levels of processing, and thus probably will not be retained at Level-1B, providing this product level is required (although the ancillary data volume will be small compared to that of the sensor data). The ancillary data that is retained will be irreversibly transformed: platform attitude and ephemeris and instrument pointing information into observation vectors and footprint locations; observation vectors and solar ephemeris into satellite and solar zenith angles and relative azimuth. Some or all of the instrument data will be irreversibly transformed through the application of nonlinear calibrations. Once used, the detector voltages and instrument temperatures will have no higher-level application.

There may be multiple levels of 1A data, particularly if 1B data is not required (due to a proven reversibility to Level-0 of the calibrated MODIS data). nly the highest level of 1A data will be archived as the MODIS Level-1A standard product.

The production of a Level-1A data record will require the assemblage of many packets of Level-0 data. These packets will have been delivered by the DHC and will be:

a. Error corrected to a bit error rate of better than 10^{-8}. (At 10^{-12}, on average only one bad MODIS bit will be encountered every day. However, at a bit error rate of only 10^{-8}, 10,000 bad bits will be encountered daily.) The packets with uncorrectable errors will be flagged as such by the DHC. The MODIS science team will require a bit error rate of no worse than 10^{-8} (and may arguably require a bit error rate of no worse than 10^{-10}).

b. Arranged in chronological order, with duplicate packets deleted, and without any gaps in coverage to no less than the 99.9% level. (Because MODIS data will be used to produce products with global coverage, missing packets will degrade the quality of the final product. Completeness to only the 99% level would result in a loss of 15 minutes of coverage; at 6.5 km per second, this is a 51°, or about a 5600 km, swath along the orbit.) The MODIS science team will require coverage to no less than 99.9%.

c. Composed of the set of all MODIS science and ancillary data packets and all platform and other ancillary data packets required for processing.

The Level-1A records will be created by collecting information from the various input data packets, unpacking the data from the packets, and organizing them into the physical records. Other information, not derived directly from the Level-0 data, will be required. This data will include calibration coefficients and algorithm/processing history information.

The production of a Level-1B data record will require only the Level-1A data as input. As such, it may be computationally efficient to produce the 1B data record immediately upon completion of the 1A record, while the 1A data is still in memory. (Note that this strategy would preclude intervention by the CST for purposes of altering the calibration in near-real-time. As conceived, the 1B data will actually be composed of four types of information: identification data, ancillary data, georeference data, and radiance data. (Because the georeference data and probably each of the first three data types will be useful to users of the Level-2 data products as well, it may be useful to put the information into a common data base shared by the Level-1B and -2 products within the MIDACS and later in long-term archive. As such, the MODIS standard product would actually be "distributed" with cross-referenced elements residing in two separate locations. In the process of filling a Level-1B or -2 order by a MODIS data user, the DADS would generate a file structure similar to that in Tables 1 and 2 by combining information from the Level-1B, -2, or georeference data sources.)

There are four basic processing steps required to produce a Level-1A product from the Level-0 data. The first is the reorganization and unpacking of the sensor data into a structure that expedites efficient application of algorithms in the higher level of processing. The second processing step is to append georeferencing information, and calibration parameters or tables. In the third, header record information is generated to facilitate cataloging and data extraction. Finally, after the higher levels of processing are completed, the data may be compressed in order to minimize the volume of the Level-1A data set. Each of the first three processing steps is discussed below.

3.3.3.1.1 *Reorganization of Data.* At the higher levels of processing, the need to remap and resample data implies that the sensor data be arranged in channel-sequential order (i.e., with sequential pixels in a scan line from the same channel). For purposes of forming images, the optimum data record structure should be based upon the scan of the instrument. A natural organization of the data would be to define the logical data record as the amount of data observed in one scan of the instrument arranged as complete swaths, one for each spectral channel. The resulting logical data record volumes would be quite large and smaller computing systems might have trouble ingesting and operating on such large logical data records.

It is conceivable that a hierarchy of logical data records could be created within the Level-1A and -1B products so that the large volume logical data record could be received by large capacity processors such as those of the CDHF. Smaller logical data record lengths could be input into mini- and micro-computers for processing and analysis. Such a hierarchy might be defined so that the largest logical data record would be one complete scan as mentioned above. Smaller data record structures could then be defined as segments of a scan.

The Level-1A processing software will reorder the Level-0 data to that of channel sequential pixels for each scan. Limit checking will also be performed at this step in the processing. The degree of segmentation that will form the smaller logical data records is TBD.

The processing software must be capable of processing MODIS observations as they are received, i.e., on an observation-by-observation basis. Conventionally, however, it is common to accumulate some amount of data before processing is begun (perhaps up to one orbit of data, or one day of data for a lower-rate instrument). If the MODIS sensor data is spectrally/chronologically reordered as a part of the Level-1A processing, then the smallest convenient parcel of data for processing is one complete scan. For MODIS-N, with eight 1 km resolution detectors along track, this is just over one second of data. For MODIS-T, with 64 1 km resolution detectors along track, this corresponds to about 10 seconds of data. If spatial resampling along the scan is performed as a part of the Level-1B processing, then the smallest convenient parcel of data for processing is a complete scan line from one detector, or about 1/6 second of data.

3.3.3.1.2 *Appended Data.* Raw georeferencing and time information, including spacecraft ephemeris, spacecraft attitude, instrument pointing (MODIS-T), time code, and GPS time correction will be appended to the Level-1A data with the minimum processing required for spatial and temporal cataloging of the Level-1A data. This will require conversion of the platform time code into universal time to give the start and stop times at least at the level of the largest logical data record. Similarly, Earth location calculations may be performed at Level-1A for portions of each largest logical data record (e.g., the locations of a corner of each swath could be calculated). This information will then be appended to provide general information regarding start and stop times and geographic coverage to users of Level-1A data.

Within each data record, the sensor data is sorted by channel, and by detector scan line within each spectral channel of data. For the case of MODIS-T, this will create a physical record approximately ten megabytes in length. The first three logical records will contain the identification, ancillary, and georeference data. The remaining 64 logical records will each contain the radiance for a single spectral channel. This structure facilitates the spectral subsetting of the Level-1B product within the DADS to meet specific data requests.

Appended to each swath of data, in the form of raw counts, will be the sensor calibration observations, calibration target temperatures, lamp currents, etc., and other ancillary data, such as instrument housing temperatures, relevant to radiometric calibration. No further processing of these data will occur at this point.

3.3.3.1.3 *Header Information/Data Compression.* All of the information necessary for cataloging and data extraction will be computed and inserted in the headers. (See the Level-1 Data Products Requirements.) A lossless data compression algorithm may be applied to the data to reduce the volume of data that must be archived.

3.3.3.2 *Level-1B Processing Steps*

To the extent possible, the Level-1A data structure will be preserved in the Level-1B products. The basic Level-1B processing steps described below are: Earth location, satellite/solar zenith angle/relative azimuth angle determination, and time calculations; radiometric calibration; data quality assessment; header record processing; and repacking.

3.3.3.2.1 *Earth Location.* Earth latitude, longitude, solar and instrument zenith angles will be calculated using the attitude and ephemeris data on the Level-1A product. These calculations may be performed only at selected anchor points to produce a sparse lattice of points which cover each swath of observations in order to reduce the computation requirement. The Earth locations and zenith angles of all other pixels in the swath will be determined by interpolation between the anchor points during Level-2 processing. Initial analyses, yet to be confirmed, indicate that it may be possible to perform the direct calculations for about 10 pixels in only one out of every 50 or 100 scan lines and still achieve the desired level of accuracy.

3.3.3.2.2 *Radiometric Calibrations.* The basic method used to radiometrically calibrate the raw detector output data involves the application of a calibration equation with coefficients such as the detector gains derived from the periodically scheduled calibration observations. This process yields a new pixel value that represents the physical value, i.e., radiance or intensity, observed by the instrument. The coefficients in this equation are determined by commanding the instrument to look at internal calibration targets of known intensity or regions on the Earth's surface with known properties.

A calibration equation will be required for every spectral channel for each scan line and detector. Thus, for MODIS-N, 8 x (30 x 1 + 8 x 4 + 2 x 16) = 752 equations will be required, and 64 x 64 = 4096 equations will be required for MODIS-T. These equations must be applied to every pixel of observed data. The sun, through a diffuser plate or integrating sphere, will likely be the principal calibration source for the visible and near-infrared channels. The calibration observations for these channels will be made (at most) once per orbit as the spacecraft passes the terminator. On the other hand, the thermal and infrared channel calibration observations will use an internal calibration target which can be viewed during each scan cycle of the instrument, except in a stare mode. Both types of channels will make use of periodic space looks, which could be performed as often as once each scan. The calibration constants will be determined by using appropriate averages or samples of these calibration observations.

The data processing steps for radiometric calibration consist of selecting the samples from the calibration observation data that provide a full solar or thermal target view, performing noise screening to reject noisy observations, and applying the calibration equation to every pixel in one or more swaths of data. Target observations must be converted into values of intensity that are, to the highest accuracy possible, traceable to known intensity standards. In the case of the solar calibration observations, seasonal trends in observed solar intensity, due to azimuth angle changes and changes in the distance to the sun, must be removed to provide normalized calibration intensities. The thermal calibration targets are monitored by a number of temperature sensors. Here, data processing must be performed to convert the temperature sensor voltages into a calibration target temperature which permits the calculation of the calibration radiance.

The calibration process will be monitored by members of the MODIS CST who will examine long term trends, instrument response, calibration target characteristics, etc. This may result in improved calibration algorithms or modifications to the calibration constants to remove trends in instrument response and or calibration target output.

Implementation of these new algorithms (and possibly the constants) will necessitate delaying the Level-1B production process, or require reprocessing of the Level-1B data.

3.3.3.2.3 *Data Quality Assessment.* Part of the Level-1B processing will include overall data quality control, and the resulting statistics will be appended to the Level-1B data. All of the information necessary to access and retrieve the data will be placed in the header records (See the Level-1 Data Product Requirements).

3.3.3.2.4 *Record Processing/Compression.* Reprocessing of Level-1 may necessitate reprocessing of all higher level products. Reprocessing of Level-1A data is not anticipated and would only be necessary if improved values of the basic telemetered information from the instrument or spacecraft are provided. The reprocessing would consist of replacing the values in the current version of Level-1A with the improved counts and updating the header information. Reprocessing of Level-1B data may be required if and when new calibration algorithms and/or calibration constants are identified by the science team. New intensity or radiance values will be calculated, and the header data and documentation will be updated. A lossless data compression algorithm may be applied to the data to reduce the volume of data that must be archived.

3.3.3.3 *Level-2, -3, and -4 Processing Operations Concept*

The CDHF sequentially derives Level-2, -3, and -4 products from the appropriate lower-level data and ancillary data. The Level-2, -3, -4 processors will be capable of performing reprocessing, special request processing, near-real-time processing, and routine processing. All MODIS data received will be processed to Level-2 within 72 hours of observation and to Level-3 within 96 hours of observation. The processing operations concept presented here stems from the Level-2, -3, -4 Data Product Requirements and consists of a description of what happens at each processing level.

3.3.3.3.1 *Level-2 Processing.* The Level-2 Processor receives Level-1B data and any necessary ancillary data. This ancillary data could include, for example, Level-1B (or Level-2) data from other instruments, either in space or ground-based. Level-2 processing derives geophysical parameters from these inputs by the application of the geophysical parameter algorithms. In data structure, the Level-2 products will be similar to the Level-1B product, that is, it will consist of orbital swaths of geophysical parameter data along with appended information.

While the Level-1A and -1B products contain all the MODIS instrument data at that processing level, at Level-2 there will exist many standard products. Each product may contain one or more related parameters. The different Level-2 products will be produced from the same Level-1B data. These Level-2 products will apply:

a. Globally, as with estimates of cloudiness and radiation budget components.

b. To specific surface types, such as sea-surface temperature or phytoplankton over the oceans only, vegetative index and soil moisture over land only.

c. Regionally, such as snow/ice bidirectional models over the polar regions, precipitation and irrotational flow estimates over the tropics, and specific interests for only certain areas of the Earth.

From I/O considerations, it may be computationally efficient to generate all Level-2 products "at the same time." Here we do not mean processing the different parameters simultaneously, but instead creating physical records for all Level-2 products from the same 1B record before processing the next 1B record. As noted in the previous section, the Level-2 products might share common georeference information. It is anticipated that this mode of processing will be possible for many or most of the Level-2 algorithms. However, certain Level-2 products will require additional information:

a. Collocated looks by MODIS-T at the same region from two or more different tilts (from within the same orbit).

b. Collocated views by both MODIS-N and MODIS-T of the same region.

c. Simultaneous data from other instruments on board the same polar platform.

d. Collocated data from instruments on board other platforms or systems, including conventional (ground, balloon, ship, or aircraft) data.

In some or all of these possible situations, the generation of the specific Level-2 product would have to occur independently, perhaps after processing of all Level-1B and the simpler Level-2 products was completed for the day of data. As additional standard Level-2 products are approved for generation, production of the parameters will commence on the day the algorithms are integrated. The processing of data computed from these new algorithms for the period prior to integration will be treated as with reprocessing: handled separately from the routine data stream and at least twice the real-time data rate.

3.3.3.3.2 *Level-3 Processing.* Using any necessary ancillary data, the Level-3 processor maps Levels-1 and -2 data onto an Earth-fixed grid associated with a desired map projection. This process includes temporal and/or spatial and temporal resolution of the Level-3 data. Standard grids are anticipated with multiple resolutions in space and time, with domains ranging from regional (e.g., polar) to global.

3.3.3.3.3 *Level-4 Processing.* As presently conceived, Level-4 products consist of model output and scientific validation analyses of lower data. Model input would be Levels-1, -2, or -3 data and could include ancillary data and/or correlative data. For example, one might compute the ocean surface carbon flux from MODIS-derived chlorophyll measurements combined with other sea surface parameters, or use radiosonde profiles and radiative transfer models to generate spectral radiances for comparison to the Level-1B measurements. A validation analysis product could be a map of the differences between the data or a scatter plot of a retrieved parameter versus coincident ground truth data. All levels of processing will include a data quality assessment which will be appended to the data product. Any information needed to access and retrieve the data product will appear in the header appended to the data. In addition, each of the products will include the following appended information describing how the product was produced: product version number, appended information from the lower level input data, geophysical parameter identification, geophysical parameter algorithm version identification, gridding description and statistics for Level-3, correlative data information, and geophysical or applications model identification for Level-4.

Level-4 processing has the potential to become even more intensive than Level-2 processing. This is because of the large amount of data that may be produced and also the potentially large number of processing instructions needed to do the complicated calculations.

3.3.3.4 *Browse Data Processing*

Browse data sets will be produced by time, space, and/or spectral averaging or sampling of the associated standard product. This results in a relatively low volume data set which can be readily transmitted electronically to be viewed rapidly by a remote user.

Browse data products will be delivered to the DADS with the same timeliness as that for the associated standard product. Browse production is considered to be a part of standard/routine processing. A subset of browse data may be delivered to the IMC. Two types of browse data have been defined: (a) 20 kilometer resolution, single-byte latitude/longitude scenes, with four spectral channels each for MODIS-N and -T as well as for each of their Level-2 parameters, eight of these scenes cover the Earth, and an additional eight of which are defined for specific domains of general interest (e.g., Antarctica, tropical Pacific Ocean); (b) four kilometer resolution single-byte cross-track/along-track scenes, with two spectral channels each for MODIS-N and -T, twenty of these scenes cover each orbit (ten during daylight only for MODIS-T). This data will require storage equivalent to less than 0.5% of the full resolution MODIS data.

3.3.3.5 *Other Processing Modes*

In addition to routine processing, there are the following processing modes: reprocessing, special request processing, and near real-time processing.

3.3.3.5.1 *Reprocessing.* The science team may request that Levels-1 through -4 data be reprocessed and would supply updated calibration algorithms and/or science algorithms. Reprocessing will occur without interruption of routine production activities and at least twice the routine processing rate. By reprocessing we mean either:

a. Updating and replacing products with data produced with improved algorithms or calibration.

b. Retrospective processing, once a new product is introduced, to increase the temporal coverage of the estimates time series.

3.3.3.5.2 *Special Request Processing.* The science team will occasionally request that a particular algorithm be tested on the CDHF before it is implemented in the routine processing procedure.

3.3.3.5.3 *Near-Real-Time Processing.* The near real-time processing mode is used to provide immediate access to CDHF processing for data items that are needed in less than the usual processing turn around times. As an example, the science team may require some Levels-1 and -2 data in time to support a field experiment. The appropriate portions of Level-0 data would be mandated and processed as priority data at the DHC and similarly processed on a priority basis at the CDHF without disruption of routine processing. The resulting near real-time products would be delivered to the requestor within three to eight hours of observation.

3.3.3.5.4 *Processing Strategy.* Driving the data acquisition and processing operations concept are the following requirements and guidelines:

a. MIDACS shall force no delays in the processing operation which preclude the direct flow of acquired data through the system.

b. The routine delivery of Level-0 data to MIDACS will be guaranteed no later than 24 hours after the observation.

c. The combined sampling rate for the MODIS-N and MODIS-T instruments will be on the order of 10^6 radiance measurements per second and 10^{11} measurements per day.

d. All MODIS observations will be processed to yield standard data products to Levels-1A, -1B, -2, and -3 by MIDACS.

e. MIDACS will process and make available data through Level-1B within 48 hours of observation; through Level-2 within 72 hours of observation; and through Level-3 within 96 hours of observation.

f. On the order of 100 standard level-2 products will be generated by MIDACS.

g. Browse data and metadata associated with the standard products will be delivered to archive with the same timeliness as the products themselves.

h. MODIS sensor data will be sequentially ordered by buffering and processing, either on board the platform or in the Level-1A processing, by scan line and then channel.

Taken literally, the first requirement clearly states that the processing software must be capable of processing MODIS observations as they are received, i.e., on an observation-by-observation basis. Conventionally, however, it is common to accumulate some amount of data before processing is begun (perhaps up to one orbit of data, or one day of data for a lower-rate instrument). If the MODIS sensor data is spectrally/chronologically reordered as a part of the Level-1A processing, then the smallest convenient parcel of data for processing is one complete scan. For MODIS-N, with eight 1-km resolution detectors along track, this is just over one second of data. For MODIS-T, with 64 1-km resolution detectors along track, this corresponds to about 10 seconds of data. For most Level-2 applications, multiple collocated spectral bands of radiances will be required to generate geophysical parameters. In some conceivable Level-2 applications, collocated observations from the same spectral channel will be needed, but from different points along the orbit (with varying zenith/azimuth angles). At Level-3, multiple orbits of data will be needed to perform spatial averaging and mosaicking.

It seems reasonable to process the MODIS data in segments, thus forcing some delay in the processing of the earliest observations of the time period covered by the segment. The exact length of the processing segment must await the results of a trade-off study considering both I/O and RAM storage factors, but will be in the range of from one scan to one orbit of data (and may be a variable). In either case, the processing system can track the data granule through a unique label (scan number and orbit number). On the order of 10^5 and 10^4 segments of MODIS-N and MODIS-T data, respectively, would be acquired daily. Once a segment of data is processed from Level-0 to Level-1A, it can then be processed to Level-1B, and then to Level-2, without waiting for additional segments to be processed. Incidentally, this procedure may facilitate the processing of subsets of the MODIS data in near-real-time without the need for duplication of effort.

Within each record, the sensor data is sorted by channel and by detector scan line within each spectral channel of data (Tables 1 and 2). For the case of MODIS-T, this will create a physical record approximately ten megabytes in length. The first three logical records will contain the identification, ancillary, and georeference (latitude, longitude, solar and satellite zenith angles, and relative azimuth) data. The remaining 64 logical records will each contain the radiance for a single spectral channel. This structure facilitates the spectral subsetting of the Level-1B product within the DADS to meet specific data requests.

Level-2 standard products can be organized in precisely the same manner, simply by substituting geophysical products for the calibrated radiances. However, there are many arguments for not putting all Level-2 parameters on the same physical record or data set. In particular: (1) the terrestrial, oceanic, and atmospheric data will ultimately reside in different long-term archives; (2) there will rarely be a simultaneous need for more than a subset of Level-2 parameters; and (3) reprocessing at Level-2 will generally occur individually for each product, and not globally as might be the case for Level-1B. Level-1B contains 64 (40) channels and Level-2 may have just a few parameters on the same product. (There may be many Level-2 products.) This opens the question as to whether it will be necessary to produce and archive repetitive information for each product. It may be sufficient to have a standard Level-2 georeference product, which is accessed by the DADS in the process of filling orders at the same time as the requested products.

It is clear that the data rates and volumes, coupled with the short delivery periods required for the standard products, require that any CDHF data processing strategy be developed well in advance of the application. Only by specifying this methodology early (to the level of the product, physical record, logical record, and algorithm) will the processing throughput be optimized and the most cost-effective data system created.

The production of MODIS products is, by definition, hierarchical: lower-level products are required as input into algorithms designed to generate higher-level products. There can be no Level-1 product without Level-0 data, and no Level-2 products without Level-1B data. However, the product levels need not always be produced in sequence: Level-3 products may be generated from either Level-1B or Level-2 data, and Level-4 products may be generated from either Level-2 or Level-3 data (or perhaps both). Many Level-2 products will be produced from subsets of the same Level-1B data, sometimes in concert with information from non-MODIS data sources.

Processing the MODIS data in segments (such as complete instrument scans) permits the data to be handled in terms of records. Some 1,000 to 10,000 of these segments of data will have to be processed through all data levels on a daily basis for MODIS-N and MODIS-T. There will be up to 100 Level-2 products generated by MIDACS. Each product will consist of one or more parameters and will have either global or regional coverage. As a result, on the order of 10^6 separate processing steps will be required to get through Level-2. This processing will occur on a daily basis, 7 days a week, 52 weeks a year. A high degree of automation will expedite the operation of this facility. It is possible that an expert system will be required to optimally control the data processing operation. The software would need to consider each of the guidelines and constraints a human operator would use: availability of the input information, memory/IO/CPU efficiency, memory/online storage management, timeliness requirements, conflicting demands for resources for reprocessing and other applications, scheduled maintenance, etc.

Table 1
Level-1 MODIS-T Product Physical Record Structure

Instrument ID
8 Byte

Orbit Number/Scan Number
16 Bytes

Data History (Input Data History/Algorithm Version/Calibration Version/Processing Date)
4,000 Bytes (Recommend ASCII)

Instrument Ancillary Data (e.g., Instrument Tilt/Operating Mode)
2,000 Bytes

Platform Ancillary Data (e.g., Observation Time)
2,000 Bytes

Data Quality Information
64 Channels * 64 Scan Lines / 8 Bits = 512 Bytes

Anchor Point Earth Locations/Earth-Sun-Satellite Geometry
20 Bytes * 64 Scan Lines * 1,294 Pixels / 4 Pixels per Anchor Point / 4 Scan Lines per Anchor Point = 103,520 Bytes

Calibrated Radiances
64 Channels * 64 Scan Lines * 1,294 Pixels * 2 Bytes = 10,600,448 Bytes

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Identification Logical Record:	4,024 Bytes
Ancillary Data Logical Record:	4,512 Bytes
Georeference Logical Record:	103,520 Bytes
Channel 1 Radiance Logical Record:	165,632 Bytes
Channel 2 Radiance Logical Record:	165,632 Bytes
Channel64 Radiance Logical Record:	165,632 Bytes
Total Physical Record Length	10,712,504 Bytes

Number of Physical Records per Orbit:	313 (Day Only)
Number of Orbits per Day:	14

Table 2
Level-1 MODIS-N Product Physical Record Structure

Instrument ID
8 Byte

Orbit Number/Scan Number
16 Bytes

Data History (Input Data History/Algorithm Version/Calibration Version/Processing Date)
4,000 Bytes (Recommend ASCII)

Instrument Ancillary Data (Mode of Operation)
2,000 Bytes

Platform Ancillary Data (e.g., Observation Time)
2,000 Bytes

Data Quality Information
94 Detectors per Kilometer * 8 Kilometers / 8 Bits = 94 Bytes

Anchor Point Earth Locations/Earth-Sun-Satellite Geometry
20 Bytes * 8 Scan Lines * 1,294 Pixels / 4 Pixels per Anchor Point / 4 Scan Lines per Anchor Point = 12,940 Bytes

Calibrated Radiances
94 Detectors* 8 Scan Lines * 1,294 Pixels * 2 Bytes = 1,946,176 Bytes

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Identification Logical Record: 4,024 Bytes
Ancillary Data Logical Record: 4,512 Bytes
Georeference Logical Record: 12,940 Bytes
Radiance Logical Record (1 km res): 20,704 Bytes
30 channels during day
15 channels during night
Radiance Logical Record (500 m res): 20,704 Bytes
8 channels during day
0 channels during night
Radiance Logical Record (250 m res): 20,704 Bytes
2 channels during day
0 channels during night

Total Physical Record Length 10,607,674 Bytes

Number of Physical Records per Orbit: 626
313 (Day Only)
313 (Night Only)
Number of Orbits per Day: 14

After standard data products are created, yet before they are placed into archive, additional processing is required:

a. The data must be certified. As anticipated, algorithms will be supplied to the CDHF by the MODIS science team along with certification criteria. Data passing these quality assurance criteria will be considered certified and will be delivered to the DADS for archival. Data failing these quality assurance tests will be delivered to the DADS as noncertified data. The science team will be notified that the certification criteria are not being met.

b. The browse data must be created. Browse data will be single-byte spectral and spatial summaries/subsets of the full resolution MODIS products.

c. The catalog information must be compiled. This data will contain information regarding the complete histories of the product and its parent data sets, including the algorithms used, DQA statistics, and any other relevant information.

d. The metadata must be generated. The metadata is a summary of the characteristics of the data product which may be broken down in terms of each processing segment. Metadata will be specifically directed towards assisting the MODIS data user in selecting and manipulating MODIS data.

This additional data must be produced within the CDHF prior to delivery at the DADS. It is possible that the DQA, browse, and metadata can be produced on a record-by-record basis, while the catalog information (equivalent to header and trailer records on a MODIS product file or volume) must await the completion of processing for the product (e.g., one day of data in the case of Levels 1-2).

3.4 CALIBRATION AND VALIDATION OPERATIONS CONCEPT

As shown in the context diagram in Figure 9, the TMCF is distributed and is composed of project-provided computing facilities used to develop scientific and calibration algorithms, verify and validate data, and to generate some specialized data sets at team members sites. As an organizational unit, the TMCF is where the science team leader provides planning and coordination for the MODIS science team members and for MIDACS. The TMCF is a distributed network of workstations at science team member locations and (perhaps) temporarily at the site of a field experiment. The network node at GSFC is where several science team members including the science team leader are expected to reside along with the CST. A group of computer scientists engaged in making the algorithms developed by the science team members more efficient and in developing software which would have general utility to all team members may also reside at the GSFC facility. The GSFC TMCF node is central to the TMCF network and will probably have the greatest amount of project-provided computing facilities.

The CST is a resource within the GSFC TMCF node of MIDACS for the activities associated with the data processing and algorithm development required for calibration. The CST will have more activities than are described here (we concentrate on the data processing aspects of calibration). This team is composed of science team members, instrument engineers, and supporting staff. Its primary responsibilities will be to see that the ground calibrations are properly performed and to provide continuity in the calibration between the pre-launch and in-flight periods. After launch, primary responsibility of the CST will be to provide calibration coefficients and algorithms to the CDHF

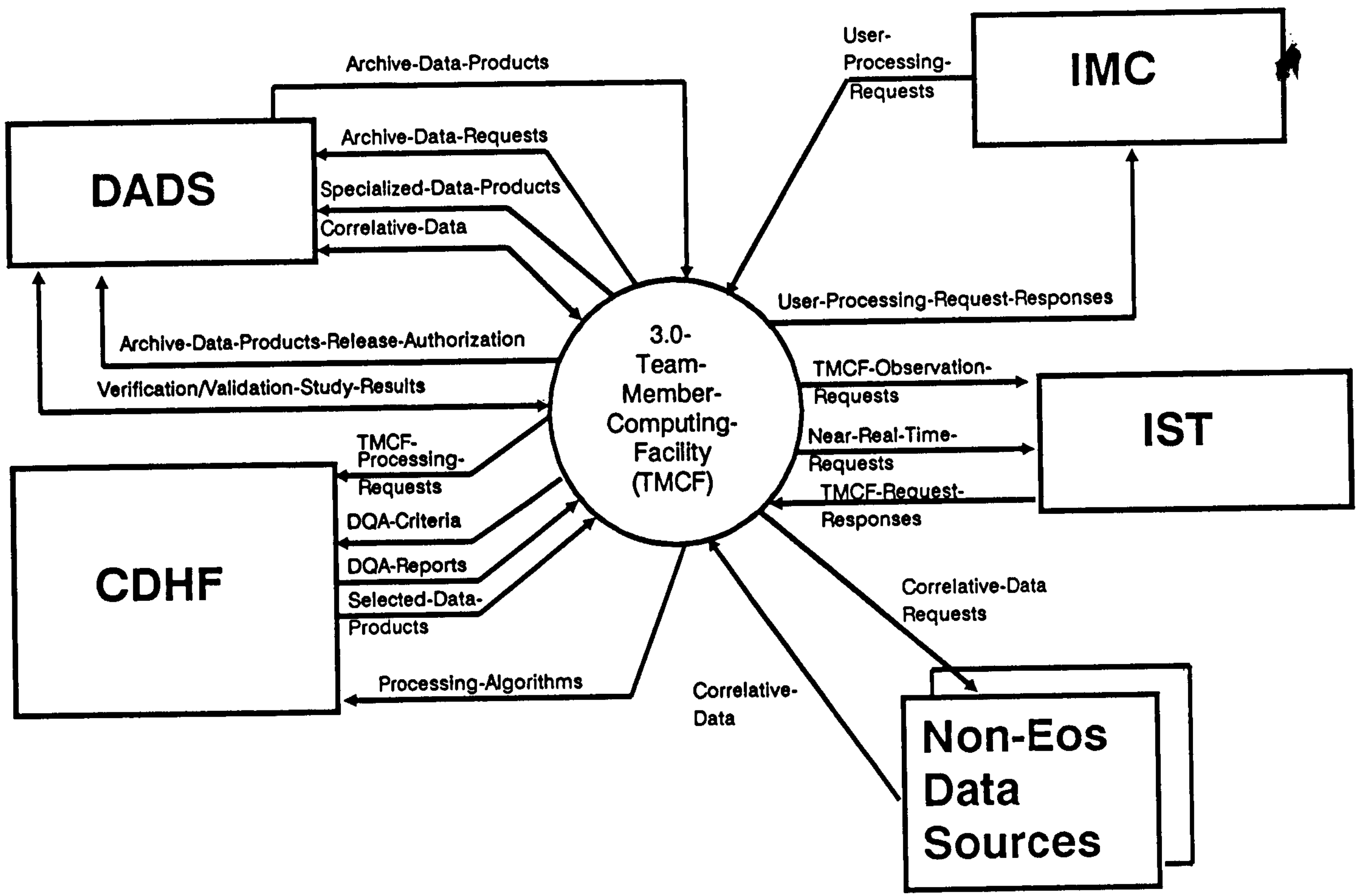

Figure 9. The TMCF Context Diagram

so that Level-1B data can be generated. The MODIS Calibration Data Products Plan provides more information on the CST activities.

In addition to communications which may be required between the TMCF's, each TMCF will require communications with: 1) the Central Data Handling Facility (CDHF), 2) the Data Archive and Distribution System (DADS), 3) the Information Management Center (IMC), and 4) non-EOS data sources.

Communications will consist of textual messages (as with the IST), interactive database inquiries (as with the IMC), and the exchange of data products, browse data products, and algorithms (as with the CDHF and DADS). A low rate (e.g., 2400- to 9600-baud line) can handle many of these communications, but a high speed bus will be required for the transfer of large data sets.

The following three major sections describe the operations of the personnel in the TMCF. The three sections follow the convention for these activities as given in the MIDACS Functional Requirement Document, namely: 1) develop and maintain science and calibration algorithms, 2) verify radiances and validate geophysical parameters, and 3) provide planning and coordination support.

3.4.1 Develop and Maintain Science/Calibration Algorithms

The Functional Requirements Document lists three major functions under the development and maintenance of science and calibration algorithms: 1) develop algorithms, 2) test and modify algorithms, and 3) deliver and certify algorithms. The operation of these three functions are described below.

3.4.1.1 *Develop Algorithms*

Science team activities in the development and maintenance of geophysical parameter algorithms and calibration algorithms will be supported by the TMCF. This facility may also be used for comparison of MODIS derived parameters with correlative data, scientific quality control, and theoretical studies and modelling to the extent that the facilities provide sufficient resources.

The science and calibration algorithms will be developed according to the MODIS Science Management Plan which is developed by the science team leader and science team members. Verification and validation study results will guide the algorithm testing, development, and maintenance.

3.4.1.2 *Test and Modify Algorithms*

The science team members will develop algorithms for operation on the CDHF computers. Strict configuration control parameters will be used in coding, testing, and documentation of the candidate standard processing algorithms, before delivery to the CDHF. Software standards, such ANSI standards or EosDIS standards, will be employed as required. The testing of algorithms will be made to insure that both accurate results are obtained and that a computationally efficient approach is adopted. The science team members will use DQA Reports from the CDHF and correlative data to test algorithms and revise current algorithms.

3.4.1.3 *Deliver and Certify Algorithms*

The fully tested and approved algorithms will be delivered to the CDHF. The delivered algorithms should include the optimization, so as to achieve optimal performance on the CDHF. Full-scale benchmarking runs (to verify efficiency, resource estimates, and algorithm correctness) will be made at the CDHF in coordination with the science team before the new algorithms become operational. DQA and certification criteria will be supplied, along with the algorithm, at the time of delivery.

The science team leader will issue Algorithm Release Announcements after the benchmark test for the newly delivered algorithms which will describe the data products generated by the algorithm and provide some information on the techniques used.

3.4.2 Verification and Validation of Data Products

Verification of the Level-1B spectral radiance values and validation of the Level-2 (and higher) geophysical parameters is an important activity of the science team members. The MIDACS Functional Requirements Document lists the three major activities in this category as: 1) receive and catalog data inputs, 2) produce special data products, and 3) perform correlative and modelling studies. The next three sub-sections describe these activities.

3.4.2.1 *Receive and Catalog Data Inputs*

Science team members will receive and catalog selected archive data products, correlative data products, selected data products direct from the CDHF, and DQA Reports. These data products are then ready for validation and/or verification activities.

3.4.2.2 *Produce Special Data Products*

The science team members may produce specialized data products within the TMCF that will be sent to the DADS to be archived. These specialized data products could be prototype data products which may eventually become standard data products, the results of an analysis at any level of MODIS data, a series of calibration scenes for one Earth target, a history of lamp outputs or blackbody outputs during the course of the MODIS experiment, or a history of the spectral calibrations.

Generation of specialized data products will require, at the minimum, the following descriptive information:

a. A catalog entry containing EosDIS descriptions of data sources, data properties, analysis methods, and attributes (e.g., location, time, wavelength).

b. A standard format to allow access from EosDIS software and processing by EosDIS archival software.

c. Documentation of data set contents, processing algorithms, and instrument characteristics.

d. An evaluation of the results including error analysis, validation tests, and relevant bibliography.

The CST will also have monitoring and analysis responsibilities which will lead to the generation of special data products. These monitoring duties include assuring that the calibrations are within limits, defining uncertainties in all calibration coefficients, and updating quality control charts for gains, offsets, temperatures, lamp outputs, and so forth. Personnel in the CST will analyze Level-0 or -1A data provided by the CDHF to derive calibration coefficients. They will be looking for changes in the calibration of the instrument, and updating coefficients as required to meet the accuracy requirements of MODIS. The CDHF will receive these updated calibration coefficients from the CST.

3.4.2.3 *Perform Correlative and Modeling Studies*

The science team members will use specialized data products, verification/validation study results, and received data products for correlation, statistical, and modeling studies. The documentation of these studies will be made by the science team members and will be provided to the DADS for archival.

3.4.3 Planning and Coordination Support

The science team members will provide input to the science team leader regarding instrument operation, CDHF data processing activities, and DADS activities. The science team leader will develop a Science Management Plan from these inputs. The functional Requirements Document splits these activities into four catagories: 1) receive and catalog requests, 2) sort and set priority of requests, 3) develop a Science Management Plan, and 4) send requests. The next four sub-sections describe the operations involved in these activities.

3.4.3.1 *Receive and Catalog Requests*

The science team leader will receive and catalog all science team member and other user observation, data processing, and data products requests, noting if they have an impact on overall MIDACS operations. Standard request forms and/or interactive database systems will be developed to facilitate the request process. The catalog of these requests will be designed to interface with the general MIDACS database format.

3.4.3.2 *Sort and Set Priority of Requests*

The science team leader is responsible for the sorting and prioritization of all requests and for tracking the request status. The Science Management Plan will provide a guide for setting priorities. Criteria for setting priorities may include considerations of the CDHF (processing time and data volume), the consensus science team members' view of the scientific objectives, EosDIS platform considerations, and so forth. High priority requests may include support of field experiments and instrument state-of-health information.

3.4.3.3 *Develop a Science Management Plan*

The science team leader will develop a viable Science Management Plan. Components of the plan include judicious use of observation time, close supervision of on-going studies and results, dissemination of data products and algorithm information, and the stewardship of the overall MODIS instrument health and operation.

3.4.3.4 *Send Requests*

The science team leader will organize and/or approve major processing requests and send them to the CDHF. Individual science team members will ensure that the processing algorithms associated with the processing requests are sent to CDHF and DADS.

Requests for special MODIS observation sequences will be reviewed by the science team leader who will resolve science conflicts and assure the Science Management Plan objectives are being met. The conflict free schedule will be delivered to ICC via the IST for further operation analysis using the MODIS operations simulator.

3.5 ARCHIVE, CATALOG, AND DISTRIBUTION OPERATIONS CONCEPT

The Data Archive and Distribution System (DADS), and implicitly the long-term archives, is the repository for MODIS Level-1 through -4 data. The MODIS data will be stored at the DADS until delivery to permanent archive centers. The IMC provides dial-up and local access to this data with the DADS distributing data products to users. Through their TMCFs, science team members will have direct access to the DADS and need not use the IMC/DADS access facilities. During the system's lifespan, the DADS also downloads specific data to designated long-term NASA/or other archives. These data sets will be available only from these long-term archive facilities. The DADS will retain the necessary catalog and metadata to locate MODIS data at any location.

As shown in the context diagram in Figure 10, data sets from the CDHF, TMCF, or other sources are supplied to the DADS for centralized storage and eventual selective retrieval and distribution to the general EOS community. All of this data will be available to all users. Even though specific data may arrive in a non-certifiable condition, it will be available to users with description of the data quality. Under designated circumstances, non-EOS access to the certified data in the DADS will be accommodated.

As shown in the data flow diagram in Figure 11, the DADS provides for the four specific functional areas of receiving data products, managing data products, processing user data requests, and generating and distributing data products. In general the DADS is not expected to perform a great deal of sophisticated processing of stored data. A specified amount of processing will be available to designated users. The following subsections each represent the operations concepts for a single functional area.

3.5.1 Receive Data

This process consists of accepting MODIS data sets, engineering data, specialized products, bibliographic data, correlative data, archived data, and ancillary data. Most of these data are expected to be generated within MIDACS (specifically within the CDHF but with special data sets being generated within the TMCF), though outside investigators can also provide data. Bibliographic data will come from selected publications. Categorization of data sets will be based on product, scene, and land/ocean descriptors.

The DADS may perform some degree of data compression, but it is expected to be of a minimal level. Browse, catalog, and metadata will be delivered to the DADS by the CDHF or TMCF with the same timeliness as the product.

3.5.2 Manage Data

This process is composed of the three subprocesses of storing data, managing catalogs, and status reporting for DADS operations and activities. Storing data consists of writing data sets to the appropriate on-line or off-line DADS storage media. When data set, metadata, and browse data storage are completed, the data sets are ready for retrieval in satisfaction of user queries.

Managing catalogs refers to updating metadata and catalog data. Metadata data elements are descriptors that currently include calibration coefficients, product start and stop

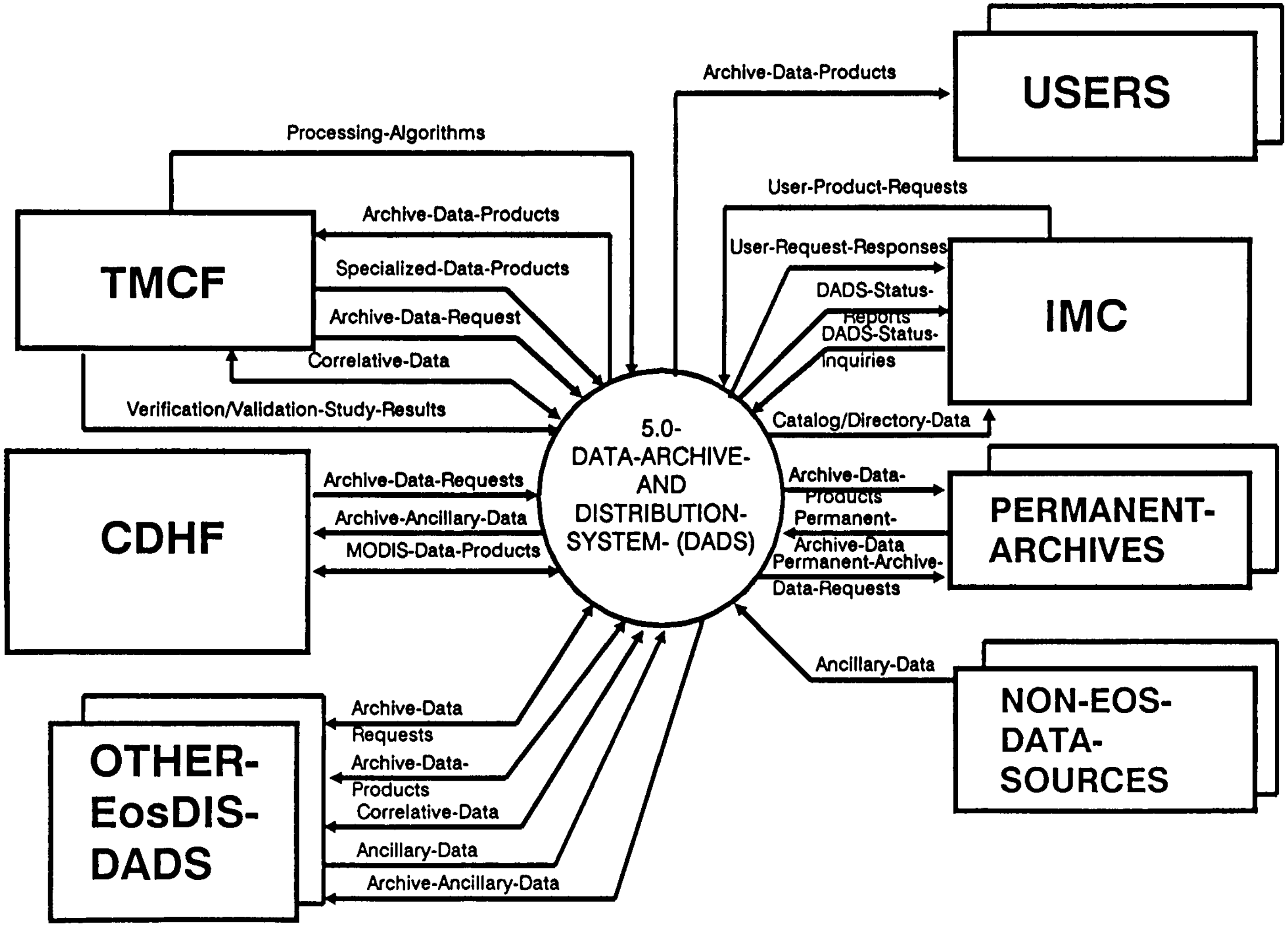

Figure 10. The DADS Context Diagram

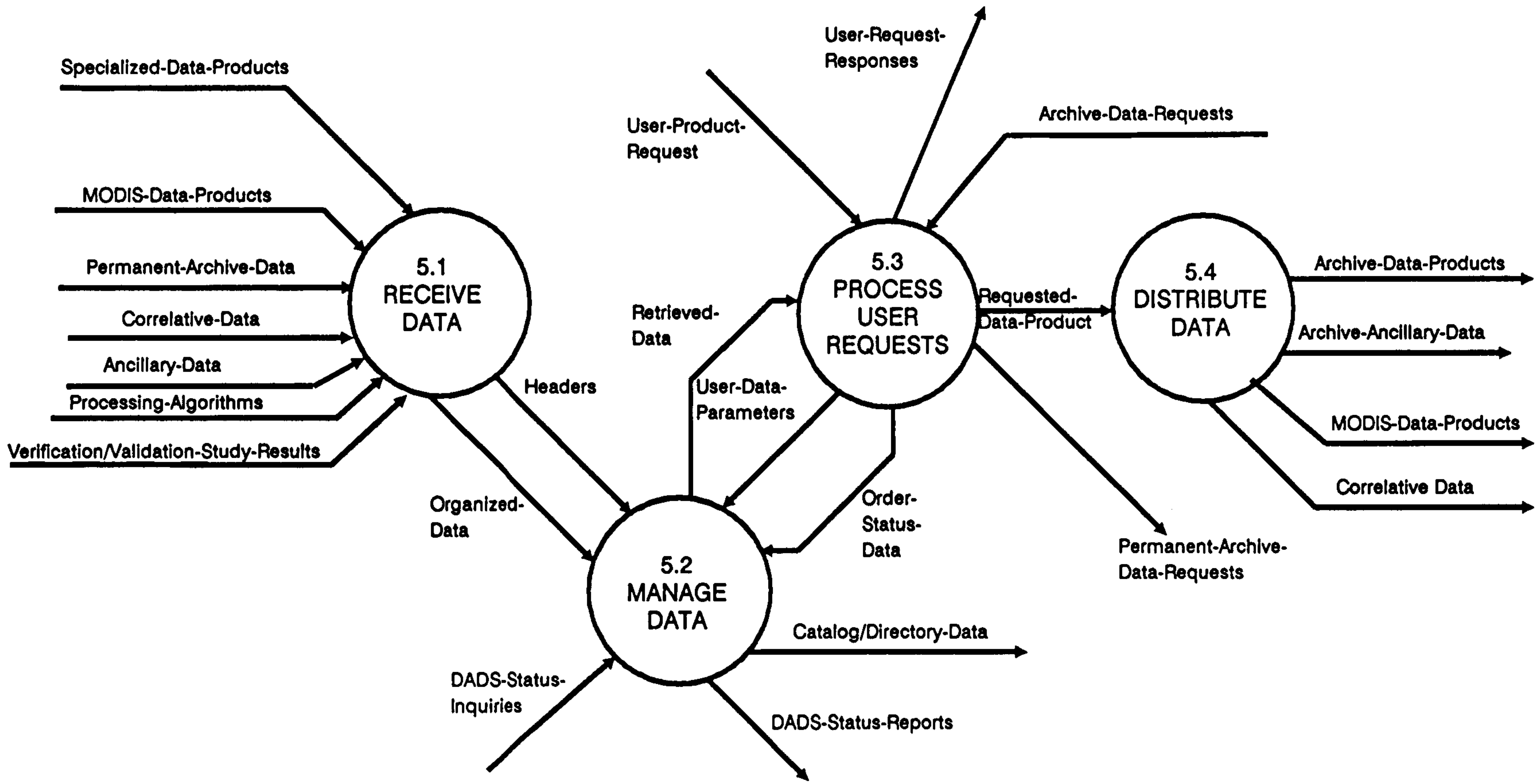

Figure 11. The DADS Functional Data Flow

times, data quality flags, and platform ephemeris. Catalog data elements currently include data set ID, type, group, location, history, and ownership. Both metadata and catalog entries will be available for query. Upon receipt in the DADS, metadata and catalog data are transmitted to the IMC where they support user query activities.

In addition to monitoring computer resource performance and use levels, the DADS maintains complete records on MODIS data sets and other products that are requested by and provided to users. Order status is maintained and made available to users in terms of orders waiting for DADS data and orders pending the availability of other EOS archived data. Users are kept current on their balances, and accounting data are included in resource utilization and performance reports sent to the IMC.

3.5.3 Processing User Requests

The production and scheduling of catalog query and archive data products is performed by the DADS. For 90 percent of the time, the first data set is currently expected to be retrieved for DADS-resident data within 100 seconds. If off-line data sets are involved, 90 percent of the time, the first data set is expected to be retrieved within 30 minutes. Up to three days may be required for retrieving data from other EosDIS DADS facilities. Standing orders are processed according to their periodic scheduled execution times.

DADS access for most users is through the IMC with science team members having direct access through their TMCF. Some image subsetting and/or decompression may be possible for some data sets with the bulk of this type of processing provided by the CDHF as part of standard products. The DADS accepts two types of data set requests. The first is a result of a query processed by the IMC (or sent from a TMCF) and forwarded to the DADS for satisfaction. TMCF data requests are expected to be in the form of commands directed towards specific data sets. The second is a standing order on file with the DADS for a standardized group of data sets that is predicated on time, location, or other conditions. As data sets meeting these parameters are acquired, they are forwarded to the requesting user.

For IMC-routed requests, the DADS locates the necessary data sets, notifying the IMC on the process. Users can request information on any of their outstanding data set requests. Any information pertinent to the retrieved data sets, such as instrument activities or reprocessing, is forwarded with the data sets. Transmission media will be selected on the basis of data set quantity and other factors.

3.5.4 Generating Products and Distributing Data

Based on the user's preferences, data quantities, and other factors, retrieved data sets will be electronically transferred to a specific off-line media. Shipping/transmission to the user then follows. Distributed data sets include information on how they were generated, as well as other data pertinent to data values. Reports will be prepared on user activity, data sets retrieved, and other topics relevant to managing the DADS.

3.6 USER ACCESS OPERATIONS CONCEPT

Until transfer to long-term archive centers, the DADS is the designated repository for Levels-1 through -4 MODIS data sets, engineering data, specialized products, correlative data, and ancillary data. The DADS also provides data from other EOS DADS or from designated archives. The IMC/DADS contains the catalog and metadata necessary to access the data sets at these other facilities.

3.6.1 DADS Access Points

Both dial-up facilities and hardwired terminals will be located in the IMC. Most users access the DADS via these facilities. Science team members have a DADS access capability via their TMCFs and can also use the general DADS dial-ups or terminals.

3.6.2 User Verification

Upon accessing the IMC and/or DADS directly, the user's ID is validated for DADS usage. If it is necessary, the user's account balance is verified as being able to pay for the requested data sets' shipping.

3.6.3 Menu-Driven Query Generation/Correction

Users can either enter queries directly in the IMC/DADS query language, or can compose queries through IMC-provided menus. The latter would allow selection and combination of specific data elements, types of outputs, ordering of these outputs, and logical relationships of data element values for retrieval. This process is iterative, continuing until a correct query is entered or the user terminates the session. Science team members have the option of using this IMC-provided facility or directly entering retrieval commands for specific data sets to the DADS.

3.6.4 Query by Example

The IMC/DADS provides samples of generic queries a user can modify for his own specific purposes and needs. These queries may have been initially supplied by the IMC/DADS or by other users. The present user need only modify query components such as the data to be retrieved, sequencing and ordering of outputs, and the selection criteria, as a function of the user's specific needs. Having been already syntactically and grammatically verified, these model queries can save the user considerable menu processing time and effort.

3.6.5 Stored Queries

Within a specific IMC/DADS account, the user can save previously executed queries. The user can execute them on a periodic basis, saving the time involved in either menu processing or direct command entry. These queries can also become periodic standing orders that, after being submitted to DADS operations, are automatically scheduled and executed by the DADS. Standing orders address specified areas of interest and do not require further action by the user.

3.6.6 General Query Library

Users may elect to send copies of their queries to the query library and can browse the query library for queries provided by other users that are relevant to their needs. Relevant queries can be copied into the user's directory and modified as necessary to meet the user's requirements. Prior to insertion in the library, a user provides the required level of documentation, including the query, describing its logic and operation in a standardized manner, and providing actual output to prove the query operates correctly.

3.6.7 Data Types Provided by the IMC/DADS

Available data types include MODIS Levels 1-4, quick-look, browse, meta, catalog, ancillary, bibliographical, and any specialized data sets provided by a TMCF. The DADS will be able to access data sets in other EOS DADS. When requested data is located in a permanent (long-term) archive, the DADS will notify the user of name and location of that archive.

3.6.8 User-Oriented Information Provided by the IMC/DADS

The IMC/DADS notifies the user if the user's present account balance is insufficient for retrieving and shipping the requested data sets. Upon completing the logon sequence, the IMC notifies users of the latest orbits for which data sets are available. For requests being processed the user is also notified within 100 seconds (90 percent of the time) of the beginning of retrieval processing. The user is also notified if requested data sets are available only through other archives, requiring the user to contact these archives directly. If requested data sets are located in other EOS DADS, the user is notified of the expected delays in retrieval of up to three working days. Upon request the user is given the status of any requests still being processed by the DADS.

3.6.9 Disposition of Retrieved Data

Retrieved data sets are transferred to the appropriate media (for example, computer-readable or hardcopy) and transmitted or shipped to the user. A specified number of data sets may be electronically transmitted to the user's terminal.

3.6.10 Billing and Housekeeping

Users are billed for chargeable services, data set storage and shipping media, and other services and activities from the IMC. The appropriate entries are made to their account. Periodic reports are prepared on user activity, data sets retrieved, and other topics as directed by the IMC.

4. MIDACS SCENARIOS

This section presents MIDACS scenarios for the routine planning and scheduling, routine processing, near real-time processing, real-time processing, TOO, emergency operations, calibration operations, and algorithm development and implementation. A scenario for user access to the data produced by the above scenarios is included. A timeline of events is presented where possible.

4.1 ROUTINE PLANNING AND SCHEDULING SCENARIO

The routine planning and scheduling of MODIS is simplified by the nature of the instrument operational capabilities and the number and types of commandable instructions. Since the duty cycle of the MODIS-N and -T instruments compliment is 100% (50% for the reflected energy channels) and 50%, respectively, a set of commands such as those for the pointing (tilt), channel selection, gain, and day/night mode switching are uploaded. Nevertheless, the ICC must simulate the instrument resources and geophysical environment, and generate commands for the observation request issued by the science team or IWG. An overview of the routine planning and scheduling is presented in Table 3 showing the event, lead time, and the interface of responsible facilities or centers.

Table 3
Routine Planning and Scheduling Events

Event		Lead Time	Interface
1.	IWG science plan	1 Month	IWG to ICC
2.	Orbit prediciton	1 Month	FDF to PSC
3.	Core Resource prediction	1 Month	PSC to EMOC
4.	Special orbit product	1 Month	FDF to ICC
5.	EMOC transmit Resources & Guidelines	1 Month	EMOC to ICC
6.	Resource Usage predict	1 Month	EMOC to PSC
7.	Develop Initial Schedule using IWG plan & science observation request	3 Weeks	ICC
8.	TDRSS Scheduling	3 Weeks	PSC to NCC
9.	Initial Schedule Sent	2 Weeks	ICC to EMOC
10.	Conflict Resolution	2 Weeks	EMOC/ICC
11.	Schedule Core System	2 Weeks	PSC
12.	TDRSS forecast	2 Weeks	NCC to all
13.	Orbit predict update	1 Week	FDF to PSC to EMOC to ICC
14.	Active schedule issued	1 Week	NCC to PSC
15.	Schedule payload ops.	1 Week	EMOC to PSC
16.	Command generation	1 Week	ICC to EMOC
17.	Conflict Resolution	5 Days	PSC/EMOC/ICC
18.	Stored Commands forwarded	5 Days	ICC to EMOC to PSC
19.	TDRSS Schedule update	5 Days	PSC/NCC
20.	Core System Command Generation	Days	PSC
21.	Update schedlue based on science team request	Days	ICC
22.	Update Conflict Resolution	Days	ICC/EMOC/PSC
23.	Schedule adjust	Days	EMOC/PSC
24.	Uplink of Commands	1 Day	PSC
25.	Platform Resource update	Hours	ICC/EMOC/PSC
26.	Commanding	-- (T)	On board
27.	Command verification	Hours (T+)	PSC/EMOC/ICC
28.	Science team request for TOO and conflict resolution	Hours/Days (T+)	ICC/EMOC

The following paragraph gives a brief timeline of events highlighting those directly involving the ICC. The timeline of these events are also shown in Figure 12. The science team will interface with the ICC for the development of initial schedule and updates to resolve schedules and to initiate and develop TOO request. These interfaces are shown by the upper boxes in Figure 11. All times shown in Figure 12 and stated below are approximate. The table and figure use a reference time, T.

T minus 4 weeks. From one month to three weeks before implimentation of the schedule on board the platform, the following tasks are performed. The IWG will provide the science plan priorities TOO procedures to the ICCs and their PI/TLs and to the EMOC. The IWG plan covers a four- to six-month period, begins two to four weeks after the end of the IWG meeting, and is distributed to the ICC. The FDF will provide any special orbit related products to the ICCs as negotiated. The EMOC makes a rough allocation of resources among the payloads of platform resources based on the IWG plan. Guidelines to be used in scheduling instruments will be provided as well. An example of a guideline could be to request that MODIS alter its operation over an area of the earth where the IWG has planned other instrument observations in order to avoid resource conflicts with the other instruments operating at that time. These guidelines would be used to reduce the potential for conflicts during the scheduling phase. The EMOC provides the ICCs with the rough estimate, guidelines, IWG plan, and orbit information. The EMOC then notifies the PSC of roughly how the core system resources are expected to be used based on the IWG plan.

At T minus 3 weeks, using the EMOC information, the ICC will develop an initial schedule based on the IWG plan, the science team leader's direction, and approved observation request from the science team or approved researcher requests received from the researchers via the IMC. All request are made to the ICC through the IST. The science team leader's priorities and procedures are followed in developing the schedule. Observations that are coordinated with other instruments are scheduled in coordination with the other ICC. New observation requests may be input into the ICC scheduling process by the science team or science team leader at this time. These observation requests may include requests for data or instrument operations used to support routine data collection or field experiments. Observation requests input at this time will aid in the development of the TDRSS coverage required to meet these requests. The active TDRSS schedule may impact the timeliness of the requests at a later point in the timeline.

The MODIS-N may have a simpler scheduling operation. The ICC will need only to work on the exceptions, for example, a safe mode for orbit adjusts, or a standby mode when higher priority operations combine to require that this instrument use less resources, near-real-time field experiment support requiring TDRSS scheduling, or a special infrequent calibration mode.

An instrument like MODIS-T is likely to be more complicated to schedule. As with many of the MODIS-N channels, it will only operate over the illuminated portions of the Earth because of dependence on visible channels. MODIS-T can also be tilted foreward and backward for special stereo or stare modes of operations.

At T minus 2 weeks, the EMOC receives the initial schedule requests from the ICC. It identifies conflicts and resolves them by using the IWG plan and priorities as a guideline and by working with the affected ICCs. The ICC works with the EMOC and other ICCs to resolve any conflicts. The science team leader may appeal any EMOC decisions to the Assistant Project Scientist or the Project Scientist. Any operation that is tightly coupled with the core system operations is coordinated with the PSC. The core system

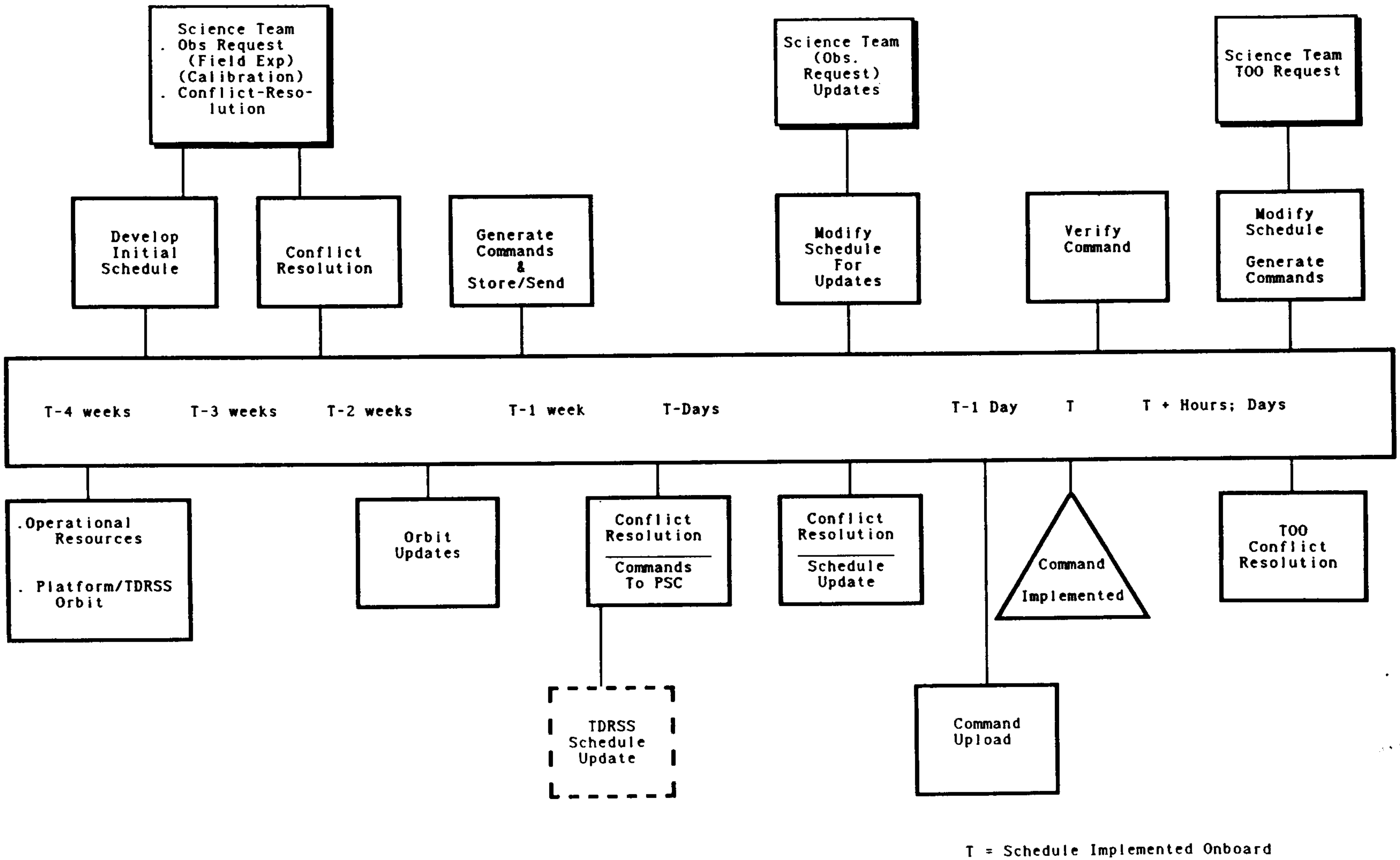

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Figure 12. The ICC Planning and Scheduling Timeline

operation are then scheduled. Operations that are greatly influenced by the payload operations are coordinated with the ICC.

At T minus 1 week, the ICC develops the commands to implement the schedule. The commands are checked within the ICC to insure that no instrument constraints or restrictions are violated. The stored commands are then forwarded to the EMOC.

During the final days before the commands are implimented, the PSC, the EMOC, and the ICC resolve any conflicts between the payload operations and the core system operations. The EMOC forwards the stored commands from the ICCs to the PSC. The ICC modifies the schedule to accommodate late observation requests made by the science team, updated information (e.g., more accurate orbit data), cloud cover information, field experiment request, and so on. The EMOC will then resolve any conflict caused by the additional requests by denying the request, moving other observations, allocating unused resources, requesting more resources from the PSC, or requesting relaxation of platform constraints from the PSC (e.g., battery depth of discharge constraints). Any schedule changes are distributed to the ICC.

At T minus 1 day, the commands are uploaded to the platform.

At T, the commands are implemented for instrument control following the schedule developed by the ICC.

At T plus hours or days, the ICC handles any requests for targets of opportunity. The science team leader, using IWG guidelines, determines whether the phenomenon qualifies as a TOO. The ICC coordinates the modifications in the schedule with the EMOC and the PSC. The procedures for observing the TOO will be predefined for many cases. Similar processes occur for schedule changes caused by payload, TDRSS, and platform problems.

The routine scenario discussed above is only one of several routine planning and scheduling processes ongoing at the ICC at any given time. Figure 13 presents a weekly workload for developing and generating the schedule and commands for the IWG plan or observation request. As shown in this figure, there will be several phases of scheduling that the ICC will support during a predetermined period (shown in Figure 13 as one week). Observation requests that may impact one schedule will, therefore, also impact other schedules which follow and are in a different phase of development. An example of this would be a TOO request made after the first T. This request would either be incorporated into the next week's schedule, or result in a near-real time change to the current schedule, depending on when the request was made.

4.2 ROUTINE PROCESSING SCENARIO

Routine processing of MODIS data takes place at the CDHF. This processing requires the performance of three basic functions: receive Level-0 and ancillary data from the DHC and additional ancillary data from other sources for Level-2+ processing; manage the processing; and apply the algorithms to produce MODIS data products at Levels-1 through -4. The process management includes handling both the input data and processing algorithms and distributing the resulting MODIS data products.

This scenario for the routine production of cloud parameters and outgoing longwave radiation (OLR) is presented here as an example of a general type of processing in which MODIS data will be coprocessed with data from other EOS instruments. The results will be atmospheric parameters such as global temperature profiles, water vapor profiles, total

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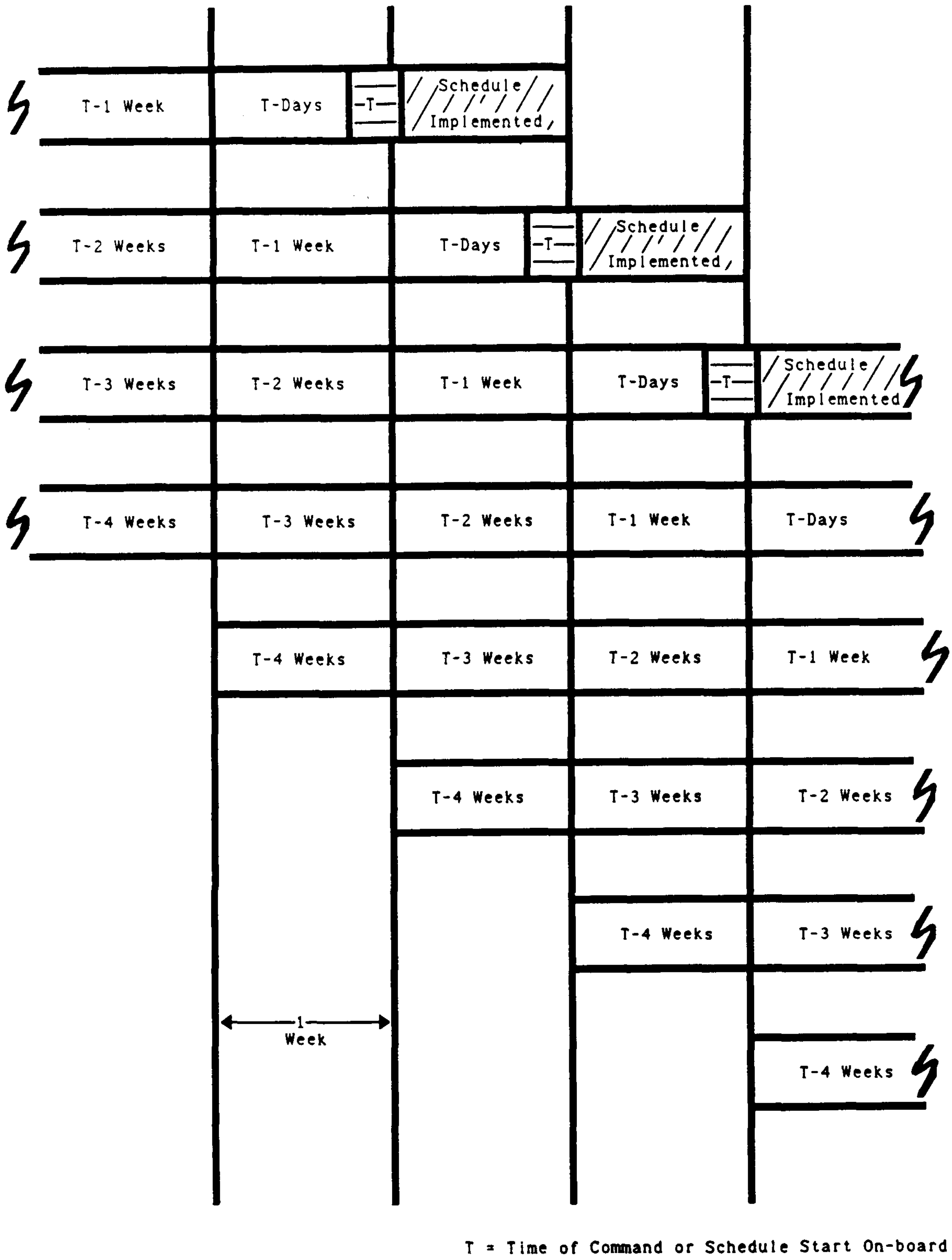


Figure 13. The Weekly ICC Routine Planning and Scheduling Workload

ozone, cloud parameters, and precipitation. The data flows that describe this scenario appear in Figure 14.

4.2.1 Global Cloud Parameter and OLR Algorithms

It is assumed, in this scenario, that the processing algorithms have been developed and tested on TMCF computing facilities and then tested in final form on the CDHF prior to implementation in routine processing.

This scenario involves the coprocessing of data from two different types of instruments. Data from the Atmospheric Infrared Sounder (AIRS) and the Advanced Microwave Sounding Unit (AMSU), which provide specific multispectral observations (complementary to MODIS) at a coarser horizontal spatial resolution, will have already been used to derive atmospheric temperature and water vapor profiles and surface temperature. These derived parameters are supplied as ancillary data to the CDHF, having been stored temporarily at the DADS until required, and then combined with thermal infrared MODIS-N data at relatively high horizontal spatial resolution to produce four global geophysical parameter data sets:

a. cloud top pressure (mb)
b. cloud fraction (%)
c. cloud longwave radiative forcing (W/m^2)
d. OLR (W/m^2).

These four products are assumed to be produced globally at full 1 km horizontal spatial resolution at Level-2. Level-3 mapped cloud parameters and OLR are assumed to be produced at lower temporal and spatial resolution. The Level-3 data products are designed with the scientific application of the data in mind and will probably be the most useful product for the scientific community. Level-3 products will be formatted to be easily inserted into general atmospheric circulation models. The Level-3 format will also expedite scientific-validation comparisons between these and other MODIS products and in situ data and model calculations.

The basic input data to the Level-2 processing are MODIS Level-1B thermal radiances at the full horizontal resolution of 1 km and AIRS/AMSU Level-2 atmospheric temperature and water vapor profiles and surface temperatures at 50 km resolution.

The MODIS-N 1B data used here are Earth-located and radiometrically calibrated observations consisting of seven 15 micron and three 4.3 micron radiances that are sensitive to atmospheric CO_2 (atmospheric temperature), one 11 micron and two 3-4 micron atmospheric window radiances (surface temperature), a single 9.6 micron radiance sensitive to atmospheric ozone and a single channel in the visible and near-infrared to measure reflected solar radiation (for a total of 15 channels).

A retrieved temperature sounding may be invalid because of excessive cloudiness or nonconvergence of the solution. In this case, "6-hour forecasts" produced by a general atmospheric circulation model operating outside of EosDIS will be used. These "forecasts" are the first guess temperature and water vapor profiles and surface temperatures which are produced using radiosonde temperature and water vapor measurements, surface measurements of temperature or climatological guesses of these profiles. These fields are required as ancillary data.

The algorithms used for this type of processing will involve solutions of atmospheric radiative transfer equations and generally employ iterative mathematical operations. Such

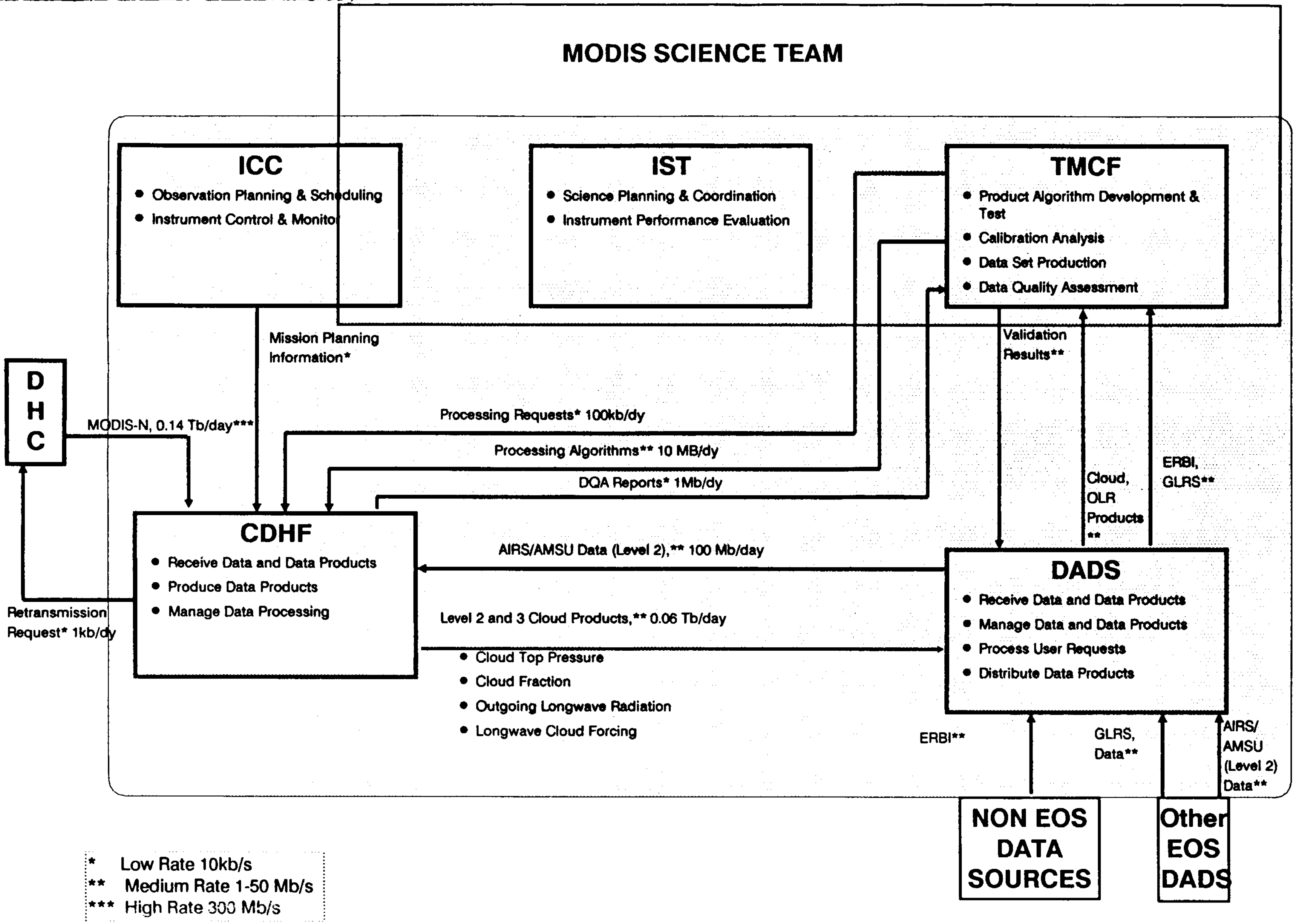


Figure 14. Routine MIDACS Scenario For Atmosphere (Cloud Parameters and OLR)

algorithms are computational intensive and require relatively large amounts of processing time.

There are no special EOS observation sequences needed for this scenario other than a 100% duty cycle. The data products will be produced from standard observations by MODIS, AIRS, and AMSU.

4.2.2 Processing Timeline

The TMCF will send processing requests and processing algorithms which contain the DQA criteria, to the CDHF. These algorithms will have been validated, tested, and coded according to EosDIS software standards by the TMCF.

Level-0 data, ancillary data, and retransmitted data are received by the CDHF from the DHC. This data will be received by the MIDACS CDHF within 24 hours of observation. The CDHF will test this data against mission planning information from the ICC for completeness and accuracy. If any received data is unacceptable, the CDHF will send the DHC a retransmission request. Level-1B data will be available for Level-2 processing 48 hours from observation.

The Level-2 processing will combine MODIS Level-1B and AIRS/AMSU Level-2 data. It is assumed that Level-2 AIRS/AMSU data are available within 48 hours of observation. For this scenario, the CDHF will acquire AIRS/AMSU Level-2 atmospheric temperature and water vapor profiles and surface temperature at 50 km resolution from the DADS. The DADS will need to receive this data from the AIRS DADS. The Level-2 processing to produce the cloud parameters and OLR will then be done within 8 to 24 hours. Level-2 processing of these parameters will have been done within 72 hours of observation, the same as the Level-2 MODIS products not requiring other instrument Level-2 data.

The Level-3 processing will require as much as an additional 8 to 24 hours of processing time on the CDHF. It is anticipated that the Level-3 processing will produce daily products, and it may require that all 24 hours of the Level-2 data be available before the processing can begin. The CDHF will then transmit the finished Level-1, -2 and -3 data products to the DADS within 8 hours of the completion of the processing or within 120 hours of observation. In the course of Levels-1 through -3 processing, the CDHF will generate DQA reports and send them to the TMCF. Browse data and metadata data associated with the standard products will be delivered to the DADS with the same timeliness as the products themselves.

This scenario assumes that Levels 1-3 processing is done in sequence. The scenario satisfies the performance requirement that the MIDACS CDHF will process data through Level-1B within 48 hours of observation, but does not necessarily satisfy the Level-2 and Level-3, (72 hr/96 hr) performance requirements. Certainly, it should be possible to do some of the processing steps in parallel. In addition, the DHC will probably begin transmitting Level-0 processed data to the CDHF within 8 hours of the collection time. Hence, the delay to the Level-1 processor would be 8 hours. The Level-1A processing can begin before all of a 24 hour block of data has been received. The same is true of the Level-1B processing.

Through the DADS, the TMCF will request the Earth Radiation Budget Instrument (ERBI) data from another EOS DADS to statistically validate the retrieved OLR product. This comparison will serve as an indirect validation of the cloud products since the OLR is highly dependent on clouds. GLRS data will be used to validate the cloud top pressure (height) retrievals. The TMCF will perform these validations after requesting subsets of the Level-2 and -3 products from the DADS. TMCF validation results will then be sent to DADS to be archived.

4.3 NEAR-REAL-TIME PROCESSING SCENARIO

4.3.1 Planning

The MODIS science team keeps the science team leader informed as the planning for an upcoming field experiment develops. Specific information of interest includes the start date and duration of the experiment, its location, the MODIS Level-1,2, and 3 data required, and the timeliness requirements for the data. This communication occurs within the distributed TMCF and also involves an interface to the science team leader at the IST.

4.3.2 Delivery of Support Plan

The planning concludes with a formal plan for the field experiment, as well as the definition of the MODIS near-real-time data sets required to support the experiment. The experimenter delivers the plan electronically to the team leader at the TMCF and the IMC for approval. In this scenario, as an example, the plan is as follows:

Experiment Purpose:	Examine Gulf Stream frontal boundary
Experiment Start Date:	December 17, 1998 (in 60 days).
Experiment Duration:	14 days
Experiment Location:	Cape Hatteras, NC, and neighboring Atlantic Ocean
Timeliness Requirements:	Daily; within six hours of real time (to support in situ measurements taken by three oceanographic vessels, directed by the team member in response to the MODIS parameter behavior
Coverage Requirements:	A single MODIS scene (2000 km square); two scenes every third day depending on the POP-1 orbit.
Level-1B Data Required:	15 channels MODIS-T (without sunglint); 2 channels MODIS-N
Level-2 Data Required:	15 standard products
Level-3 Data Required:	10 products on 10 km MODIS standard grid 5 products or 1 km MODIS standard grid

4.3.3 Scheduling and Commanding

After review, the team leader approves the data request and forwards it via the IST to the ICC as an "observation request." Following predefined procedures for planning and scheduling, the ICC tests the plan on the simulator and then reviews the plan with the EMOC to test for conflicts. After approval of the plan by the EMOC, a "command load" is generated and sent to the EMOC/PSC. The command load assures that the MODIS instruments will observe the experiment region at a given time and that the data will be designated by the on-board processor for near-real-time processing by the CDHF. This command procedure is tested by generating command loads to tag data for production of a near-real-time trial scene for the target region well in advance of the experiment (as a rehearsal).

4.3.4 Data Processing

The CDHF is notified by the team leader via a "TMCF Processing Request" to anticipate the near-real-time data. The request provides the exact processing requirements. The automation code in the CDHF is programmed to provide the near-real-time processing for the experiment as requested. The CDHF tests the data processing software and procedures by processing the trial scene and produce the requested scene data in near-real-time and delivering it to the DADS as "Archive Data Products."

4.3.5 Data Archival and Distribution

The DADS is notified by the team leader to anticipate the receipt of the near-real-time data as soon as it is generated from the CDHF and is provided with the delivery address and communications methodology for delivering the data to the experimenter. The DADS verifies the delivery procedure by receiving, storing, and then transmitting the data from the trial scene, as well as the requested scene data, in near-real-time within the required timeliness.

4.3.6 Monitoring and Evaluation

Both the scientist concerned and the team leader are kept apprised of the outcome of the trial scene experiment, as well as kept regularly informed (daily) of the status of the near-real-time processing as the experiment takes place. Corrective action is taken if required. The scientist and team leader evaluate the success of the near-real-time support shortly after the conclusion of the experiment.

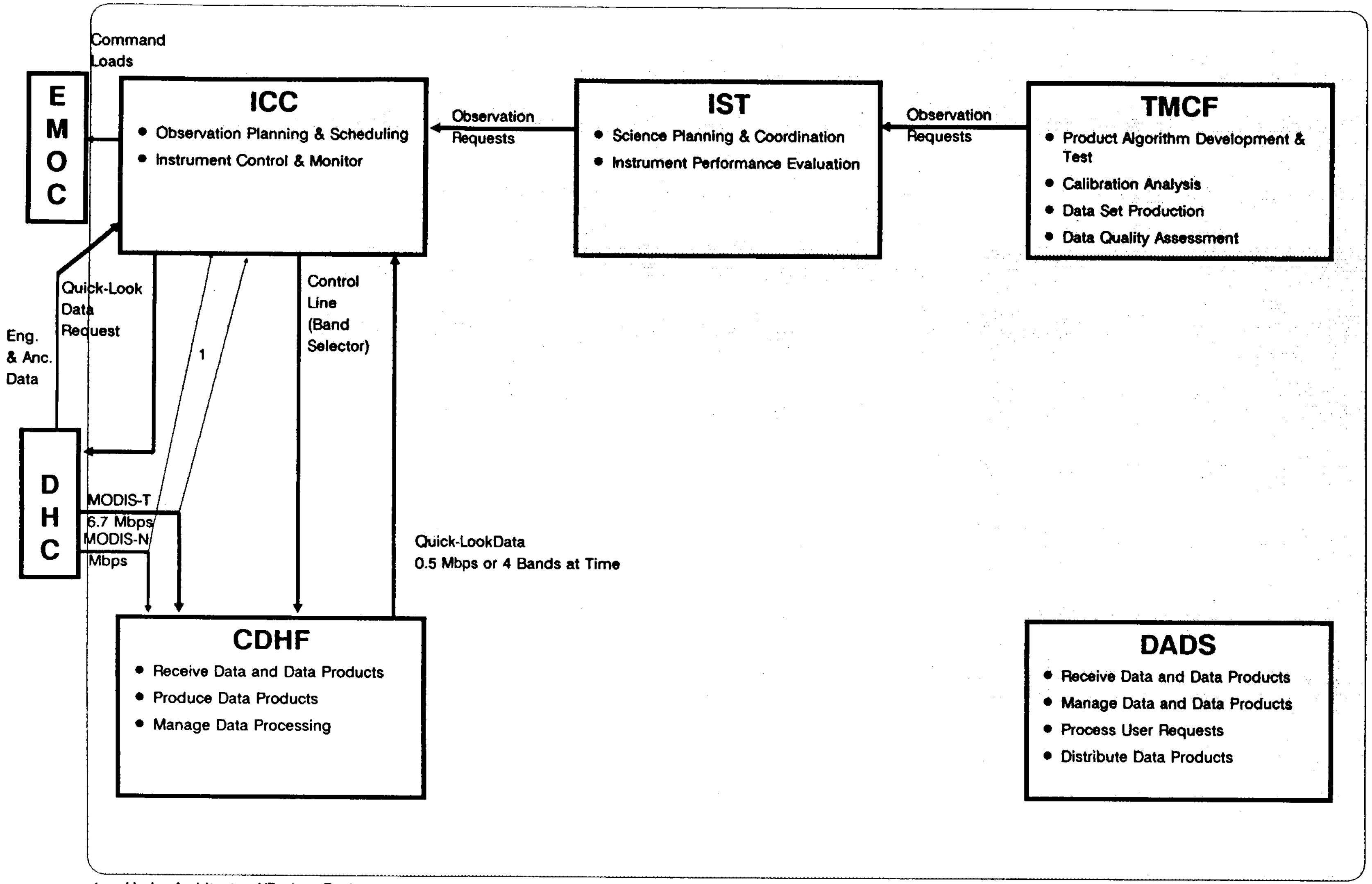
4.4 REAL-TIME PROCESSING SCENARIO

Real-time here refers to two separate data streams. The first one is engineering data collected and transmitted to the TDRSS without buffering. The second type is playback data that is transmitted to the ICC without buffering at DIF and DHC. Both types of real-time data are needed to monitor the MODIS instrument for the health and safety. The second type is needed to support field experiments. The output from this monitoring can be used to correct anomalous instrument behavior or aid in field experiment decisions. A scenario to monitor the science data in real-time is presented here and shown in Figure 15.

To provide this requirement, the MIDACS will need to manipulate the selected MODIS science data return in real-time. This data will be separated into selected MODIS-T and -N bands that result in building of scenes of data that are $(2000\ \mathrm{km})^2$ in coverage. Investigators will select the specific spectral bands of interest in real-time at ICC.

4.4.1 Delivery of Real-Time Plan

In a field experiment support scenario, the real-time plan begins with an observation request by the science team leader that is implemented by the ICC into the planning and scheduling scenario. This request may be implemented as routine, or as an update to an ongoing observation. In either case, the request for real-time instrument data must be coordinated with the TDRSS schedule generated at the Network Control Center (NCC). This is done to provide real-time science data at the selected field experiment site. The experiment team member uses this observation data to develop field experiment criteria and strategies. After review and approval by the experiment team, the observation



1 = Under Architectural/Budget Review

Figure 15. Real-Time MIDACS Scenario for Instrument Monitoring (as of 12/7/88)

request is forwarded to the ICC via the IST. In the following scenario the plan is as follows:

Scene start time:	Orbit 2 of December 17, 1998
Number of Scenes:	One
Duration of Scene:	5 minutes
Instrument requested:	MODIS T and N
Selected Channels:	1 through 4 for MODIS T & N (ground support)
Processing Level:	0 (ground support)

The ICC then uses the observation request in a simulation to ensure the correctness of the request and reviews it with the EMOC as in the planning and scheduling scenario.

4.4.2 Data Processing

For both types of scenarios, the ICC will receive data from the DHC. The DHC, with appropriate information for identification of the MODIS real-time instrument packets, then routes the instrument packets in real-time to the MIDACS. It is anticipated that the DHC will transmit all MODIS engineering data received in real-time to the MIDACS for health and safety monitoring. For field experiment support, the experiment team has the option of using playback data in a priority mode. The playback data will contain the requested data and will be downlinked on the next TDRSS contact following the requested quick-look time. If the experiment team is using playback data for quick-look analysis, then the data request sent to the DHC contains the requested start and stop times for a segment of the playback data to be sent to the MIDACS without level zero processing.

4.4.3 Science Data Monitoring

The DHC electronically transmits the real-time or playback segment of instrument packets to the MIDACS where they are stored, buffered, and the bands to be monitored are selected. The selected bands are then processed to the requested level and displayed on workstations in the ICC (separate workstations for MODIS-T and -N). Up to four bands can be selected, per instrument in real-time, by a science team member located at the ICC. Only the quick-look data that is selected is stored.

4.4.4 Evaluation

The science team member monitoring the MODIS science data will appraise the status of each selected band. From this appraisal a request can be made to correct anomalous instrument behavior and to direct field experiment activities. Monitored data will be stored at the ICC for analysis of instrument health and safety at a future time.

4.4.5 Quick-Look Architectural Issue

At this time, it is estimated that the MIDACS element receiving the direct real-time MODIS data must have a MIPS rating of greater than 70 just to sort and select the desired quick-look channels. Since this is several orders higher than required to support an ICC's control and monitor function, the quick-look data may have to be processed to the desired level at the CDHF prior to display and manipulation at the ICC.

4.5 TARGET OF OPPORTUNITY (TOO) SCENARIO

Dynamic phenomena, such as volcanic eruptions, insect infestations, and human produced or related events, will be detected by MODIS. These events represent targets of opportunity for scientists and require a quick response both by the scientist and MIDACS to study these phenomena. The scientist, presented in this scenario as a science team member, will notify the science team leader of an ongoing or predicted target. Specific information necessary to operate the MODIS instruments to study this event will result in the generation of command or observation request by the science team leader which is sent to the ICC via the IST. These requests will impact the current schedule at that time.

4.5.1 Planning

Since the majority of TOO events may not be predictable, the following scenario discusses MIDACS operations for an unpredicted event. The request does not follow the current instrument schedule. Researchers or a science team member deliver a TOO request to the science team leader at the TMCF, the IST or the IMC for approval. The approved request is then transmitted via the IST to the ICC. As an example, this observation request may contain the following information.

TOO type; Red Tide
TOO start time and duration; 1998, July or August, 3 days
TOO location; Gulf of Mexico
Timeliness requirement; Daily, 3 days
Near Real-time requirements; First day
Instrument Unique Operations; MODIS-T tilt

The TOO scenarios are similar in nature to the Near Real-Time scenarios when the observation data needs to be processed quickly.

4.5.2 Scheduling and Commanding

The IOT at the ICC will respond in an appropriate manner to the request. To minimize turnaround time, the ICC may use pre-generated commands developed for such an event or generate the commands from a simulation of the request. The latter may be a shortened process due to the nature of the request. The command load is then verified and sent to the EMOC for resource conflict review. The commands are then uploaded to the instrument according to standard procedures during the next available TDRSS contact. If the event is to be observed in near real-time, command loads will be generated to assure that the instrument properly tags the instrument packets for near-real-time processing. Once the TOO event is over or the duration time span of the observation request to monitor the TOO is exceeded, commands will be issued by the IOT to resume the current weekly schedule that was interrupted.

4.5.3 Monitoring

The ICC will notify the CDHF of the request in order for the CDHF to provide the appropriate processing functions and will notify the science team leader of the status of the request. The IOT will monitor the engineering and science data to ensure that the instrument is responding to the command load. If an anomaly is discovered in the operations, corrective action will be taken by the IOT the approval of the science team leader.

4.5.4 Data Processing And Archiving

Processing of observation data for targets of opportunity will follow near real-time processing requirements closely. The CDHF will contain or be provided with an automation code to provide the near real-time processing for the event as requested. The DADS will be notified by the science team leader to anticipate the receipt of the TOO data as soon as it is processed. As in the near real-time processing scenario, the DADS verifies, stores, and transmits the data to the originator of the request.

4.6 EMERGENCY OPERATIONS SCENARIO

An emergency command situation may be detected in several ways; by the onboard computer system, from observation of the MODIS instrument by the IOT within MIDACS, or from an EMOC request due to other instrument behavior. If MODIS exceeds its operational resource envelope, the onboard flight data system may safe the instrument. It will then be the responsibility of the IOT and the science team to determine and correct the condition. We assume that anomalous behavior of the MODIS instrument, resulting in the emergency situation in this scenario, is discovered by the IOT and the science team during the course of routine monitoring of engineering and science data. For the following scenario, a detected failure in the mechanical operation to tilt MODIS-T is used as an example.

4.6.1 Routine Monitoring of Instrument Behavior

The IOT located at the ICC will monitor the engineering and ancillary data from the instrument and the platform. The data will be analyzed by the IOT using predefined checks and procedures, such as limit checking against expected parameters. The expected parameters will be derived before launch by the instrument design engineers, the CST, and the science team. Algorithms used to monitor the engineering data will also be develop by the CST and science team and incorporated into the ICC monitoring procedures. The ICC will be manned 24 hours a day to ensure the constant monitoring of the MODIS instruments.

Science data will also be monitored in the ICC. This task will be accomplished by a science team member using a workstation in the ICC. A selected set of up to four channels will be simultaneously monitored to analyze the collection and quality of science data.

4.6.2 Detection of Anomalous Behavior

We assume here that, during the daily observation of engineering data it is discovered that the power for the control of MODIS-T tilting is below its minimum limit check parameters. The IOT then verifies that the ingested engineering data is correct and current within the MIDACS itself. The science data monitoring function is also checked to determine if the results concur with the engineering and ancillary monitoring results. The science data scene indicates that the current command load for MODIS-T tilt is not pointing the instrument in the proper direction. These checks are accomplished in a timely manner. The EMOC is then notified of the condition to warn other instruments of an anomaly in the platform resources. The IOT will concurrently contact the science team leader to verify the condition as an emergency condition and to jointly determine a response to correct it.

4.6.3 Emergency Response

The IOT has analyzed instrument behavior during the prelaunch phase and most emergency command situations (e.g. safing) have been anticipated. Critical command loads that were pregenerated and waiting to be transmitted to facilitate a rapid response are then brought on-line. The pre-generated commands are updated in response to the understanding of the instrument behavior. This is also done whenever possible to cover new or previously unanticipated instrument behavior possibilities. The IOT then sends the pregenerated command to place the instrument into a safe mode, such as a nadir-pointing orientation. If this command does not correct the condition, procedures are then followed to take future corrective action. This action may simply be to accept the current tilt angle until instrument and platform engineers analyze the anomaly and recommend corrective measures. The instrument is then safed according to approved procedures by uploading a new safing command.

4.6.4 Analysis of Emergency

Once the instrument has been safed or the condition corrected to the approval of the science team leader, analysis begins to determine the cause of the condition. This is done using data archived within the ICC and the DADS, along with the analysis taking place both by the IOT at the ICC and by the CST within the GSFC TMCF. The cause in this scenario was a power decrease due to a temporary degradation of the solar panels on the platform. After the power level resources were resolved and other instrument power resources reduced, commands were sent to MODIS with the next scheduled upload to resume the current operations plan for tilting.

4.7 CALIBRATION OPERATIONS SCENARIO

The scenario presented here provides a chronological summary of how calibration operations may proceed, who will be involved, and how they will interact. Since the scenario assumes that calibration planning is done in one week blocks, most of the steps in the scenario will be occurring simultaneously as each of the weekly plans progresses through the system.

T - 5 weeks: The CST consults with the HIRIS CAL and with other instrument calibration teams on the EOS platform, informing them of the upcoming calibration plans. The calibration observation plans of the two or more instruments are coordinated so that instrument intercomparisons are possible.

T - 4 weeks: The CST decides on a schedule of observations that they want for a one week period, four weeks in the future. They wish to examine intensively their Earth targets of opportunity. The calibration scientist, or his designate in the CST, using an interactive menu-driven program developed jointly with the IOT, determines the times (GMT) and orbit numbers when the EOS platform will be over the selected targets within 10 degrees of vertical during the week in question. The CST incorporates this derived information in the proposed observation plan, an example follows.

4.7.1 Initially Proposed Weekly Schedule

All days: Deploy solar diffuser plate on one orbit each day as satellite crosses the Earth's terminator (nearest 00 GMT).

Day 1: Normal operations. No special mode changes.

Day 2: Observe Earth targets: White Sands, the central Sahara, the Atacama desert, and Greenland during orbits n, n+3, n+4 and n+9.
MODIS-T in nadir position.
During a night orbit, sequence lamps through 3 levels.
Tag all special data sets for CDHF/TMCF.

Day 3: Observe Earth target: South Pacific region.
MODIS-T in nadir position.
Tag data for CDHF/TMCF.

Day 4: Night time orbit: observe dark side of Earth, perform spectral calibration, and perform electronics calibration.
Tag data for CDHF/TMCF.

Day 5: Observe targets: White Sands, the central Sahara, the Atacama desert, the South Pacific region, and a second South Pacific region.
MODIS-T in nadir position.
Tag data for CDHF/TMCF.

Day 6: Observe targets: the Arabian peninsula, Alice Springs, and the Kalahari Desert.
MODIS-T in nadir position.
Tag data for CDHF/TMCF.

Day 7: Observe targets: White Sands, the central Sahara, and the two South Pacific regions.
MODIS-T in nadir position.
Tag data for CDHF/TMCF.

4.7.2 Scheduling and Commanding

T - 3 weeks: The science team leader received the proposed plan from the CST one week ago. He also received proposed observation plans from several other science team members and from other users via the IMC. As part of the initial screening process, the plans are entered into an expert system on a computer which identifies possible conflicts in observations. The science team leader and science team members are provided with copies of the list of observation conflicts. The science team leader in consultation with the science team members reviews the conflicts. The CST proposal to observe the Atacama desert on days 2 and 5 requires MODIS-T to be in the nadir position which conflicts with proposed ocean chlorophyll observations requiring MODIS-T to be in a tilt position. The science team leader decides ocean chlorophyll measurements have higher priority based upon IWG guidelines and eliminates the Atacama desert observations from the CST observation plan. The conflict free plan is sent to ICC using the IST.

T - 2 weeks: ICC tests the plan on their simulator and finds no problems. ICC in consultation with EMOC reviews the impact of the plan on the platform operations. In this case we assume a conflict is found requiring the CST to cancel or re-schedule the night observations of the lamps scheduled on day 2. ICC notifies the science team leader who in turn notifies the CST of the conflict. The CST revises their plan to have the night observations on day 3 rather than day 2. The conflict resolution procedure described above is repeated with no further observation changes required in the second go-round. The HIRIS CAL and other instrument calibration teams are kept informed of all developments within MIDACS relating to the coordinated calibration plan.

T - 1 weeks: The ICC writes the command sequences which will be executed in the following week. These command sequences will include a tag which will be appended to the header of the data requested by the CST so that they can easily identify the data sets that they requested. An alternative scenario would require the CST to simultaneously notify CDHF of the observations plan and require CDHF to somehow extract the requested data from the data stream.

T + hours: However the data is extracted, the CDHF writes the data to a disk on an account maintained by the CST at the CDHF. A mail message is sent to the CST notifying them that new data has arrived. The CST downloads the new data to their TMCF for more detailed analysis.

T + 12 hours: The CST uses the newly acquired data to derive gains for the detectors. Based upon this analysis, the CST decides that several detectors have changed sufficiently that revised calibration coefficients are required. An updated table of coefficients is sent to CDHF with the time at which it becomes effective. The CDHF uses the coefficients in its routine processing of Level-1A data to Level-1B. Simultaneously, the CST sends this information to the DADS for archiving.

T + 3 days: The CST contacts the IMC and requests the HIRIS data taken in the plan be sent from their DADS to the CST.

T + 5 days: The CST receives the HIRIS data.

T + 1 week: The CST uses the Earth TOO data for more detailed analysis of the MODIS instrument performance. Much of this analysis may be of the form of interactive image processing using a version of the Land Analysis System (LAS) software of Landsat or PACE (the software package used by the Canadian Centre for Remote Sensing). Typically the HIRIS spatial and spectral resolution would be degraded to match the MODIS resolution and then the differences between the two equivalent images would be studied. These analyses may confirm previously observed instrument changes have occurred, may lead to re-processing, or the development of new calibration algorithms.

The following provides some comments on how the derivation of the calibration coefficients might proceed at around T + 12 hours. The CST is responsible for maintaining the calibration of the MODIS instruments in orbit. One of their performance requirements is that they derive revised calibration coefficients in sufficient time such the processing of Level-1A data to Level-1B radiances is not delayed. A second performance requirement stipulates that Level-1B processing be complete within 48 hours of receipt of Level-0 data. Three alternative scenarios present themselves:

a. The calibration coefficients are automatically derived using the CDHF and normally there is no additional examination of the data by the CST. This scenario is highly probable, and it is likely that one entire orbit's worth of data will be used to derive the calibration coefficients.

b. The CST has the capability to examine a subset of Level-0 data. Since Level-0 to Level-1A processing will take about 24 hours, this time period can be used by the CST to derive calibration coefficients.

c. The CST has the capability to examine Level-1A data. This case would leave the CST very little time for analysis.

The actual scenario that will emerge is as yet undetermined.

4.8 USER ACCESS SCENARIOS

Two typical scenarios are presented to typify the types of user access to the DADS, the retrieval/shipping of selected data sets, and support of specialized user activities.

4.8.1 A Science User Who Relies on System Menu Processing

A research scientist is trying to determine the scope of MODIS data available with information content related to ocean and lake biological activity. The scientist works at an institution with a current MODIS account. The scientist comes to the IMC and reviews the hardcopy catalog entries in his areas of interest and looks at the low resolution browse data in the browse publications. After making preliminary notes on the geographic areas containing the desired levels of the parameters of interest (e.g., chlorophyll, surface temperature), he logs into the system on one of the hardwired terminals.

The scientist first accesses the literature search menus and selects a keyword-based search using relevant parameters and specific techniques of analysis. The system locates 15 publications, and the applicable journal articles' abstracts are queued to the terminal. The system also indicates which articles are based on MODIS data or other data accessible through EosDIS. The scientist selects seven for printout in the IMC. The processing for these services is billed to the institution's account.

The scientist now selects the MODIS data selection menus and requests images identified from a metadata-based search. These Level-2 and Level-3 product metadata values include chlorophyll concentration ranges, chlorophyll fluorescence ranges, times of observations, measures of cloudiness, and calibration quality flags. Because of the scientist's interest in modified retrieval methods for some of the parameters, the scientist also requests the Level-1B data used to generate these products and their processing algorithms (including documentation and sample benchmark data). The scientist also selects the option of having these algorithms and their documentation printed in the IMC.

Within 15 seconds the system notifies the scientist (via his terminal) his query has been queued for execution and asks for confirmation for the charges being made to the institution's account. Confirmation is given in the form of the scientist's individual user code. Ten minutes later a message appears indicating the first of the 350 datasets meeting the retrieval criteria has been located. The off-line media will be available for shipment by 3:30 PM of that same day. The system recognizes the scientist's terminal to be an IMC terminal and the scientist is given the option of either having the products (optical tapes in this case) shipped or taking personal delivery. He selects the latter. The system acknowledges and provides an order number and tape numbers to be used when he requests the tapes from the data clerk.

Using the menus the scientist requests a second look at the eight articles he did not select for printing. He then selects two of them for printing in the IMC. The institution's account is accordingly billed. The scientist uses the menus to check the progress of his dataset order and logs out of the system.

4.8.2 A First-Time Knowledgeable User

In May, 2007, a researcher is studying the change of effluent characteristics on the Mississippi River over the past 10 years. The researcher needs spring and fall MODIS-N Level-1B imagery with less than 20 percent cloud cover. This user is a non-NASA funded university researcher who knows the instrument, location, and time coverage.

The user first contacts an EosDIS representative to set up an account on the EOS system. Billing arrangements are made with the university and the user is given a unique EOS user ID.

From a university terminal the user logs into the IMC to locate the available data. The user already knows the MODIS data (channels and processing level) relevant to his research and wants to review any similar research previously performed with the EOS data. Using the menus he selects the option to review published papers identified with keywords such as "effluent", "sediment", "turbidity", and "Gulf of Mexico". Several papers are read and selected for transmission to his terminal. The cost and target address are user-verified and the material is sent.

Through the selection menus the user specifies metadata values in terms of date/time, latitude, longitude, specific channels, and less than 20 percent cloud cover and/or sunglint. The system provides a list of available images, their geographic limits, and any quality control flags. Selected browse data meeting the query criteria are viewed.

The user selects the order menu and the desired images are identified for copying to computer-readable media and subsequent shipment. The user repeats the query/browse/ordering process for each relevant time period and geographic area. For selected images the system provides processing documentation such as instrument calibration and processing algorithm information.

After the user indicates the session is completed, the DADS displays completed order forms on his terminal. These forms list the images requested, supporting documentation, media to be used, and the cost. The user verifies the forms' data and the order is queued for processing and shipment.

4.8.3 Science Team Member Validating a New Level-2 Product

A scientist on the MODIS science team needs data to study a new Level-2 terrestrial vegetation index being produced as a standard product within the CDHF. The required data will be a Level-2 and -3 data set of vegetation types from a few selected study regions that coincide with a recent period of interest.

As a science team member, the scientist knows the parameter of interest (10 km gridded vegetation indices), the time period required (the first 10 days of the current month), and that the MODIS data were acquired within the two geographic areas and periods selected. The scientist logs into the DADS through the TMCF. The scientist requests the data sets meeting his needs. They are copied to the appropriate media and shipped.

The scientist logs out of the DADS and into the IMC. This gives access to the selection menus for performing a search of the relevant literature. (TMCF-based access to the DADS requires the user to issue specific data set retrieval commands. The IMC provides menu processing and query generation.) Several archived publications, as well as the algorithms and other standard documentation, are located through a keyword search and transmitted to the scientist's terminal.

The TMCF provides the scientist with the computing support necessary for performing research with the Level-2 product.

4.9 ALGORITHM DEVELOPMENT AND IMPLEMENTATION SCENARIO

Algorithm development and implementation will be occurring both prior to launch and after launch. In this scenario, we list some of the steps that may be encountered in a typical developmental program with a typical time line.

T - 5 years: The science team member receives sufficient computing resources from the MODIS Project Office so that he can start algorithm development. (T is the implementation date and possibly the launch date.)

T - 2 years to T - 2 months: A prototype algorithm is developed and debugged by a science team member. It is submitted to the CDHF for timing tests. Computer scientists at the GSFC TMCF node and CDHF begin examination of the software code and look for methods to increase the efficiency such as vectorization. The science team member continues to check the accuracy and validity of the algorithm.

T - 2 months to T - 1 month: Using lower level MODIS data generated by the CDHF and using the CDHF computers, the science team member and computer scientists have interacted to increase the code efficiency, with runs requiring about 1/3 to 1/100 the computer time that the initial code required. No loss in accuracy has occurred and the CDHF computer architecture is fully exploited.

T - 1 month: The algorithm is formally delivered to the CDHF by the science team member, along with all certification and DQA criteria needed for autonomous processing.

T - 1 week: The CDHF automated/expert system processing code is updated to bring the new algorithm on line.

T: The algorithm is applied to Level-1B data and generates a Level-2 product. Browse, metadata, and catalog data are generated. The certification criteria are tested.

T + 1 day: DQA indicates a change in the algorithm is needed. For the purposes of this scenario, we assume that the initial validation tests indicate a problem exists with the algorithm and that the certification criteria are not being met. The CDHF withdraws the algorithm from routine processing. The defective data are sent to the DADS as uncertified and are only available to the science team.

T + 2 months: The science team member has located the problem in the code and fixed it. The revised algorithm is resubmitted to the CDHF and the CDHF reinstalls it in its Level-2 processing stream.

T + 2.2 months: Archival of the geophysical parameter starts since it is now a certified standard product. The science team leader, based upon the most recent validation studies, certifies the algorithm and issues an Algorithm Release Announcement. Simultaneously, retroactive processing on the backlog of data, taken prior to the implementation of the algorithms, is used to derive the new standard product. The required input data is acquired from the DADS and sent directly to the CDHF for processing at twice the processing rate.

T + : As the MODIS experiment continues, the scientific algorithm is updated and maintained as required. The maintenance of algorithms is an ongoing aspect of the experiment.

5. OUTSTANDING ISSUES AND UNCERTAINTIES

With an expected launch of the NPOP-1 in late 1996, we have some eight years to wait before the first data taken in flight by the MODIS-N and MODIS-T instruments is received and processed. Before this milestone is achieved, the MODIS data system must be fully designed, built, and tested. At this stage, however, the Phase-B design studies for the instruments are not yet completed, the members of the MODIS science team have not yet been selected, and the structure and concept of the EosDIS is still evolving. It is not surprising that there exist some uncertainties, at this time, in specific areas of the MIDACS operations concept. The uncertainties fall into two categories: those driven through a lack of specific definition of the EosDIS environment and those driven due to a lack of specific knowledge concerning the MODIS instruments' capabilities and the science team members' proposed research objectives.

5.1 REAL-TIME MONITORING OF MODIS DATA

Engineering and science data taken by the MODIS instruments, as well as selected platform ancillary data, must be monitored in the ICC. Ideally, all data of possible utility would be available in real time with a 100% duty cycle. However, the primary downlink will be through the TDRSS, and it is anticipated that the platform will have access to the TDRSS for only portions of each orbit. Each TDRSS access will be generally scheduled well in advance of the actual contact. While there will be an alternate multiple-access low-rate data path for the transmission and verification of emergency commands, the TDRSS link will be the sole path for downlinked data destined for the monitoring function within the ICC. Engineering and science data taken between TDRSS contacts will be stored on board the platform for playback and downlink at the time of the next TDRSS contact.

Under these circumstances, it will not be possible to monitor the instrument with a 100% duty cycle in real time. With priority-playback processing at the DHC, the data may be monitored with a 100% duty cycle either in real-time or shortly after reception by the DIF. It is anticipated that the platform and instrument ancillary data (engineering/housekeeping) will be packetized separately from the science data and automatically routed to the ICC.

There is a requirement that science team or IOT members located in the ICC monitor four channels each of MODIS-N and MODIS-T data in real time, and that the choice of the channels being monitored be selectable in real time. Even though the first method is used in this report, there are three possible methods for achieving this:

a. The data are buffered on board the platform by the instrument data system during each scan. Data from different channels are packetized separately. All MODIS data is treated as either real-time or priority-playback data by the DHC. A split pipe flow may exist, with Level-0 processing functions performed twice for some MODIS data, allowing the MODIS ICC to receive the data quickly and the CDHF to receive the data after the gaps in coverage have been filled. Within the ICC, the headers of the Level-0 data packets are examined and data from selected channels only are ingested into the monitoring data base; non-selected data are lost.

b. As in the previous example, the science data is buffered and reorganized prior to the generation of data packets. However, in this scenario, the ICC uplinks to the on-board data system in real-time the selected subset of channels to be monitored. The on-board data system installs the real-time/priority-processing designation and ICC address in the header of the packets of data required for monitoring. Upon acquisition at the DHC, the designated packets of data are delivered immediately to the ICC, perhaps with only partial Level-0 processing. Within the ICC, the data are received at a relatively low rate, unpacked, and inserted into the monitoring database. Data from unselected channels are not available with this timeliness, but may be analyzed at a later time (24+ hours after observation) upon completion of processing at the CDHF.

c. In this case, we assume that the on-board processor does not buffer the MODIS data during a scan (on the order of ten megabytes for MODIS-T). Each packet of science data then contains data from many spectral channels multiplexed together. All MODIS data is treated as either real-time or priority-playback data by the DHC. As with the first example, there is no interactive, real-time selection of channels to be monitored between the ICC and the on-board processing system. Because of the absence of on-board data sorting by channel, the science data required for monitoring at the ICC must be collated from observations contained on many packets. All MODIS data packets are required, and many aspects of the Level-0 and -1A processing are required to unpack and reorganize the data into a form useful for monitoring. The processor size required will exceed that normally associated with typical control and monitor functions and may reside on the CDHF.

5.2 IMPLEMENTATION OF ALGORITHMS FOR STANDARD PRODUCT PROCESSING

A significant savings in required computing resources can be made if algorithms are written to take advantage of the machine architecture. As the operations concepts is now written, a group of computer scientists at the GSFC TMCF node will be engaged in this activity, although as yet this group is not formally identified in other documents. They could also be useful to science team members by developing algorithms of general utility to all science team members such as subroutines that could re-image any geophysical data onto a regular grid. This single development would save each of the science team members from developing the same subroutine.

5.3 CAPABILITIES OF THE ON-BOARD PROCESSOR

5.4 NON-MODIS INSTRUMENT DATA AVAILABILITY

Non-MODIS instrument data availability from other EOS and non-EOS sources.

5.5 NEAR-REAL-TIME DATA COMMUNICATION

Communication of near-real-time data from the CDHF/DADS to field experiments.

5.6 DATA PROCESSING OPERATIONS CONCEPT

The level of meaningful detail in the processing operations concept is limited by our knowledge of the processing algorithms. Details of the processing scenarios and concepts such as the logical data record, Earth location, and calibration accuracy will evolve with our understanding of processing algorithms and end-user requirements.

5.7 CAPABILITIES AND INTERFACES OF THE MIDACS WITH THE DHC

What are the current capabilities of the DHC to support the real-time, near-real-time, and routine science data processing timelines that are required by the MIDACS? The DHC will process some data for real-time delivery to the MIDACS (ICC or CDHF) for monitoring. The DHC will also pass the priority playback data to the MIDACS, but it is still uncertain how this will be accomplished. This DHC/MIDACS interface has not been fully clarified.

5.8 ON-BOARD PROCESSING

There will be an impact to the ICC workload for the planning and scheduling/control and monitoring functions if the ICC has the added responsibility of uplinking commands for the selection of channels to be monitored. The ICC personnel would have to work more directly with the EMOC/PSC/NCC for the scheduling of TDRSS contacts to accomplish this. Also, the increase of work due to many requests for data or the rapid selection of channels would pressure ICC personnel to make quick decisions without the ability to follow defined procedures and guidelines for the checking and verification of all command loads.

5.9 STORAGE OF THE MODIS SCIENCE, ENGINEERING, AND ANCILLARY DATA

These data will be stored either at the ICC, EMOC, or MIDACS DADS. This has an impact on the required storage capacity of ICC or wherever the data are stored.

5.10 IMPLEMENTATION OF DARs FOR REAL-TIME FIELD EXPERIMENTS OR INSTRUMENT CALIBRATION

The current schedule will be interrupted for each request. The number of such requests is unknown at this time. Any request for real-time support would effect the TDRSS scheduling and, therefore, needs to be coordinated with the appropriate facility to satisfy the reqest.

5.11 HIERARCHY OF REQUESTS

The hierarchy of priorities for the requests for field experiments or real-time monitoring, and the availability of workstations at the ICC to provide support, must be defined.

5.12 COMMAND TRACKING OF TOOs AND REAL-TIME REQUESTS

The ICC must verify the command load for all commands uplinked to the MODIS before they are transmitted to the EMOC. The procedure and timeline for doing this must be defined.

5.13 MODIS/HIRIS AND JOINT SCHEDULING WITH OTHER INSTRUMENTS

The MODIS and HIRIS will have some sort of interaction not only for the planning and scheduling phase, but also for the impacts of requests for data in the real-time and near-real-time for the support of field experiments for MODIS and coincident observations for HIRIS. A prioritized scheduling process must be developed.

5.14 MIDACS SUPPORT PERSONNEL

The role of the product support analysts and the system operators with respect to the production of standard data products.

5.15 ERROR CORRECTION/GRADE OF SERVICE

Will the MODIS data be encoded (e.g., Reed-Solomon) for error correction and error corrected to a bit error rate of 10^{-10} to 10^{-12}? At 10^{-12}, on average only one bad MODIS bit will be encountered every day. However, at a bit error rate of 10^{-8}, 10,000 bad bits will be encountered daily. The packets with uncorrectable errors should be flagged as such by the DHC. The MODIS science team may require a bit error rate of no worse than 10^{-8}, or Grade II service of data transmission, whichever is lower, but 10^{-10} would be preferable.

5.16 DATA COVERAGE

Because MODIS data will be used to produce products with global coverage, missing packets will degrade the quality of the final product. Completeness to only the 99% level would result in a loss of 15 minutes of coverage; at 6.5 km per second, this is a 51° or about a 6,000-km swath along the orbit. The MODIS science team may require coverage to no less than 99.9%. Systematic coverage loss may be subject to different requirements than random coverage loss, perhaps to a factor of ten.

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7. Author(s)
D. Han, V. Salomonson, J. Ormsby, P. Ardanuy, A. McKay, D. Hoyt, S. Jaffin, B. Vallette, B. Sharts, D. Folta, E. Hurley, D. MacMillan

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P. Ardanuy, A. McKay, D. Hoyt, S. Jaffin, and B. Vallette: Research and Data Systems, Greenbelt, MD 20770
B. Sharts and D. Folta: General Sciences Corporation, Laurel, MD 20707
E. Hurley and D. MacMillan: Interferometrics, Inc., Vienna, VA 22180

16. Abstract
The MODIS Information, Data, and Control System (MIDACS) Operations Concepts Document provides a basis for the mutual understanding between the users and the designers of the MIDACS, including the requirements, operating environment, external interfaces, and development plan. In defining the concepts and scope of the system, this document will describe how MIDACS will operate as an element of the Earth Observing System (EOS) within the EosDIS environment. This version follows an earlier release of a preliminary draft version. The individual operations concepts for planning and scheduling, control and monitoring, data acquisition and processing, calibration and validation, data archive and distribution, and user access do not yet fully represent the requirements of the data system needed to achieve the scientific objectives of the MODIS instruments and science teams. The teams have not yet been formed; however, it has been possible to develop the operations concepts based on the present concept of EosDIS, the Level-I and Level-II Functional Requirements Documents, and through interviews and meetings with keys members of the scientific community. The operations concepts have been exercised through the application of representative scenarios.

17. Key Words (Suggested by Author(s))

Moderate Resolution Imaging Spectrometer	MODIS
High Resolution Imaging Spectrometer	HIRIS
Earth Observing System	EOS
EOS Data and Information System	EosDIS
Data Systems	

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